PROTECTIVE COATINGS FOR SHEET METALS IN SUPERSONIC TRANSPORT AIRCRAFT

FINAL SUMMARY REPORT
TO
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SOUTHERN RESEARCH INSTITUTE

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INTRODUCTION

Purpose

The purpose of this research was to obtain a preliminary indication of the feasibility of using protective coatings to prevent corrosion of skin materials on supersonic transport aircraft.

Scope

The program consisted of two parts: first, a survey of industrial, government, and research organizations to obtain information on the known properties of available coatings; and second, an experimental screening program wherein metal panels coated with the most promising coatings chosen from the survey were subjected to limited exposures simulating conditions expected to exist in service. The results from the program were evaluated to determine which of the coatings are worthy of further application, development, or more detailed experimentation.

Background

The development of supersonic transport aircraft involves several design problems, among which is the frictional heat that will be generated on the skin of the aircraft as it moves through the upper atmosphere at supersonic speeds. Temperatures as high as 650° F are expected to occur, making impractical the use of conventional aluminum alloys for the skin material. Although many ferrous and nonferrous heat-resistant alloys retain useful strength at 650° F, they are subject to varying amounts of oxidation, discoloration, or other forms of corrosion. Ordinary rusting in long-time exposures in the ground-level atmosphere must also be overcome if low-alloy or maraging steels are used. Therefore, some form of protective coating on the skin might be necessary to prevent corrosion in SST service.

Many types of coatings are now available for prevention of corrosion under normal atmospheric conditions, but the suitability of these coatings under the conditions to be encountered in service on supersonic transports is not known. Other coatings have been developed for more extreme conditions, but they are relatively expensive and have been designed for short life. In addition to resistance to temperatures of 650° F, desirable characteristics of coatings for corrosion protection of skins of supersonic transport aircraft are long-time stability, ease of application and repair, and adherence and flexibility to withstand the stresses and strains that will be applied in forming, assembly, and service.

PROCEDURE

Literature Survey

A survey of the literature was conducted first to accumulate the published information on the properties of coatings that might be applicable to supersonic-transport use. Sources for the literature survey included leading commercial journals, journals of technical societies, abstracting publications such as the ASM Review of Metal Literature, and government reports from agencies such as the National Aeronautics and Space Administration, Aeronautical Systems Division, and Defense Materials Information Center. The information from the literature survey was used not only for ascertaining the latest developments in the coatings field, but also for providing possible sources of information for the industrial survey.

Industrial Survey

For the industrial survey a list of 396 organizations associated with the development, manufacture, and use of coatings possibly applicable to supersonic transport aircraft was compiled. This list in alphabetical order is appended to this report as Appendix A. It was compiled from the Thomas Register, the 1961 and 1962 Materials Selector issues of Materials in Design Engineering, and various references found in the literature survey. By means of a letter and questionnaire, which are illustrated in Appendix B, information concerning potentially useful coatings for supersonic transport aircraft was solicited from each of these organizations. During the survey, personal interviews were held with several coating suppliers, and some contacts were made by telephone.

A total of 178 replies were received from the letter and questionnaire, a response of 45%. A quantitative rating system was designed to reduce the questionnaire information on the properties of each coating to a single number indicative of the relative merits of the coating. The rating system was devised by judging the relative importance of each property in comparison with each of the other properties and by assigning a maximum arbitrary rating number to each property based on its importance. The information received on the questionnaires was used to assign a relative rating within that maximum to each property of each coating.

The coatings were classified within each of six categories: metallic, organic, semi-organic, inorganic (or ceramic), other coatings, and surface treatments. Each type of coating for which a completed questionnaire was returned, or which was given consideration because of information in the literature, was rated within its own group according to the scores obtained from the sum of the individual rating numbers assigned to each property. The scores were used to determine which coatings should be selected for the experimental exposures. The selections were not made on the basis of score alone, but consideration was given to obtaining adequate representation from each of the categories. It was felt that the manufacturers from widely different fields; for example, paint manufacturers as compared to electroplaters, may have different conceptions of the adequacy of corrosion resistance, flexibility, abrasion resistance, etc.

From the use of the rating system, 22 coatings were chosen for the experimental exposures.

Experimental Program

Materials

Annealed 18Ni-9Co-5Mo maraging steel (Allegheny Ludlum 18 NiCoMo 300) was chosen as a substrate for evaluating the coatings experimentally because it is one of the least corrosion-resistant materials under consideration for the skin of supersonic transport aircraft. The 0.040-in.-thick substrate was sheared into 12 in. x 12 in. panels for application of the selected coatings. The control material selected for experimental exposures was Alclad 7075 aluminum because it is a conventional skin material used in present-day commercial and military aircraft.

A brief description of 18 of the 22 types of coatings selected for experimental evaluation by the use of the rating system is presented below. Because of the proprietary or experimental nature of some of the coatings, suppliers of the other four coatings did not furnish information of this type; in other instances pertinent details regarding composition or method of application were not furnished. We assume that this information would be made available if needed in the SST development.

Cold-Galvanized Zinc, Rust-Ban 191, marketed by the Humble Oil and Refining Company, is composed of metallic zinc in a silicate vehicle, and is reported to furnish galvanic protection to steels. It may be applied by either spray or brush techniques. It self-cures to form a continuous film of zinc bonded to the metal surface, thereby producing a coating with properties similar to hot-galvanized coatings; therefore, it has been classified as a metallic coating. A similar coating was suggested by the Galvicon Corporation.

Electroplated and Hot-Rolled Nickel coating is a development of The International Nickel Company. In this process, nickel is electroplated on steel billets by conventional methods and hot rolled to the desired plate or sheet thickness. The heating for hot rolling must be done in an atmosphere containing 5% or less excess oxygen. The reduction of the nickel coating during hot rolling is reported to be proportional to the reduction of the steel substrate. The heating and rolling produces a diffusion bond. Because the manufacturing process prevented application of this coating to the standard 12 in. x 12in. panels, The International Nickel Company furnished a sample on another maraging steel.

The Elphal Process (Electrophoretically Deposited and Rolled Aluminum), developed and reported by The British Iron and Steel Research Association (BISRA), is a method of coating steel substrates with aluminum. It is based upon electrophoretic deposition, a method wherein steel strip is passed through a slurry containing charged aluminum particles that are deposited on the strip by electrostatic attraction. The deposited powder is then consolidated into a nonporous coating by rolling and a subsequent sintering and bonding heat treatment. Because the process is still in development at present and the BISRA pilot-plant processing equipment can coat only continuous coils of strip in a maximum width less than one foot, it was not possible to obtain this coating on the standard panels. However, BISRA furnished a sample of the coating on a mild steel substrate. Plans have been made for an Elphal plant to produce 48-in.-wide sheet coated with 0.02 in. of aluminum at 40 ft per min to compete economically with hot-dipping processes.

An Electroplated Nickel and Cadmium coating was suggested by the Military Aircraft Systems Division of the Boeing Company. This coating consists of an electrodeposited coating of nickel at least 0.0005 in. thick covered with electrodeposited cadmium to minimum thickness of 0.0002 in. Following plating a conversion coating conforming to Specification QQ-P-416A Type II or its equivalent is applied, and a diffused bond is produced by heating the coated steel to 620-640° F. It was suggested that field repair of the coating would be practical by brush-plating methods. Because Boeing does not produce this coating commercially, the electroplating and conversion coating were performed by Power Plating Company, LaGrange, Georgia, and the diffusion heat treatment was conducted at Southern Research Institute.

The Vacuum-Deposited Aluminum coating, under development by the Ethyl Corporation, is a carbon-free coating produced by the vapor decomposition of an organoaluminum compound on a heated substrate. To effect the decomposition, the substrate is heated to temperatures below 482° F in the absence of air or moisture. Because of the development status of this coating, the expense and time consumption necessary to obtain it on the standard-size panels was considered prohibitive. However, the Ethyl Corporation coated six 3 in. x 4 in. samples of the maraging steel substrate. Similar vacuum-deposited aluminum coatings were suggested by the National Research Corporation and the Bureau of Naval Weapons.

Flame-Sprayed Aluminum coating, supplied by Metco, Inc., was also suggested by the Metallizing Company of Los Angeles, Inc. and by the Castings and Non-Metallic Materials and Processes Division of General Electric Company. This coating is applied in a process that involves blasting the substrate with steel grit or aluminum oxide abrasive, applying 99% pure aluminum by flame spraying, and applying a silicone sealing coat.

The Diffused Aluminum-Iron coating (Haynes-Stellite Company Coating No. C-10) was applied by a pack-cementation method in which the substrate is packed in a "particulate" aluminum material within a sealed metal retort. The retort is then heated to an elevated temperature to cause a diffusion of the coating into the substrate. A similar diffusion coating was suggested by Alon Processing, Inc.

Hot-Dip-Galvanized Zinc coatings are available from many commercial producers. One of the standard panels was coated with Prime Western Zinc by the Metal Coating Corporation. Recent experience in the automotive industry indicates that this conventional and long-known protective coating may be practical for use on SST aircraft.

The Electroless Nickel Alloy coating is the Kanigen nickel-phosphorous alloy supplied by the General American Transportation Corporation. The coating is deposited chemically in the absence of externally impressed electric current.

The Thermosetting-Polymer coating (GIC-805) was supplied by the National Glaco Chemical Co. It is a proprietary coating for which no details of composition or application procedure were reported.

The Silicone Resin Vehicle (No. 16169 Heat Absorption Paint, White Formulation PV 100X) was supplied by the Vita-Var Company and was applied by spraying techniques. It requires a baking time of 25 minutes at 275° F. The supplier applied two coats over an approved Air Force specification primer.

The Teflon in Silicone resin was suggested by Acheson Colloids Company. Their designation for this coating is EC-1697E (PTFE in silicone resin). It is applied by conventional air-atomizing spray techniques, and it requires heating to 450° F for one hour to cure.

The Catalytically Cured Silicone, which is a development of the Coatings Section of the Aeronautical Systems Division, may be applied with different types of primer systems. The standard panel for this project was coated with ASD's experimental formulation 58-5 over their experimental primer P-4. A catalyst, added to formulation 58-5 prior to its application, cures the coating at room temperature.

The Aluminum-Modified Silicone is a heat-resistant aluminum paint designated XP-310 by the Dow Corning Corporation. The coating was applied by spraying and baked for one hour at 480° F.

The Silicon-Nitrogen Polymer is a coating system under development at Southern Research Institute. It is a hexaphenylcyclotrisilazane-ethylenediamine silazane polymer blend, a mixture of silazanes (silicon-nitrogen chains) that are nitrogen analogs of silicones. The application procedure involved the preparation of a hot solid prepolymer of hexaphenylcyclotrisilazane, the preparation of an ethylenediamine silazane oil, and the mixing of equal quantities of these chemicals in a solvent. The resulting solution was then poured on the substrate and allowed to spread by tipping the panel. After application to the substrate, the coating was cured at 430° F for 15 minutes plus 750° F for 30 minutes.

The Fused-Mineral coating, Korok A-19 from The Enamel Products Company, consists of proprietary "rock-like" minerals that can be applied by flowing, spraying, or dipping, depending upon the contour of the workpiece. The coating was bonded to the base metal at temperatures in excess of 1700° F.

The Flame-Sprayed Aluminum Oxide coating, Rokide A, was suggested by the Norton Company. The standard panel was coated by the C. M. C. Corporation, a licensed contractor. Their procedure consists of the application of a flash undercoat of 60Ni-15Cr-25Fe, the Rokide A coat, and a sealing coat of silicone resin. Similar ceramic coatings were suggested by Ceramco, Inc.

The Zinc Silicate coating is an air-sprayed, self-curing, inorganic coating (ZRAS) supplied by Koppers Company, Inc. Similar coatings were suggested by Industrial Metal Protectives, Inc. and the Amercoat Corporation.

Descriptive information concerning the compositions and methods of application was not supplied for the four coatings designated as "other coatings." These coatings are: Heat-Resistant Coating 57X50 from Benjamin Foster Company, "DA-9" Aluminum from Markal Company, "Pyre-M. L." Varnish from E. I. duPont de Nemours & Co., and A-61110-50 Aircraft White from Rust-Oleum Corporation.

Special Heat Treatments

Two of the coatings (Diffused Aluminum-Iron and Fused Minerals) required that the substrate be heated above 900° F (the maraging temperature) when the coatings were applied. Although these application temperatures would be expected to have no effect on the experimental determinations (since the substrate material was in the annealed condition), the practical use of the coatings would be affected because the high application temperatures would impair the properties of a previously maraged substrate. Therefore, it was considered necessary to subject the panels coated with these two materials to a post-application heat treatment to determine whether such heat treatment would have a deleterious effect on either the substrate or the coatings. Accordingly, these two panels together with a control panel of uncoated maraging steel, were held at 1500° F in moving air in an electric furnace for one hour, air cooled to room temperature, and held in the same furnace for three hours at 900° F and air cooled to redevelop their maraged properties. Two metallographic specimens were taken from the uncoated control panel to determine whether the re-heat treatment produced the proper microstructure. The first specimen, taken after the 1500° F-air cool treatment, showed a predominantly martensitic microstructure, and the microstructure of the second specimen, taken after the 900° F aging treatment was composed of martensite plus precipitate. These typical microstructures indicated that the heat treatment applied to the three panels was satisfactory.

Experimental Plan

For the experimental operations, each of the 12 in. x 12 in. coated panels was divided into twelve 3 in. x 4 in. specimens. The cuts were carefully made by using a 1/32-in. alundum cut-off wheel in a surface grinder to prevent damage to the coatings. The surface grinder was used so that the cuts could be made in small indexed increments. Six of the twelve specimens were used for determining inherent properties and the other six for properties after exposure to heat. The properties of the coatings considered to be inherent were 1) its flexibility or ability to bend or flex with the substrate, 2) its resistance to mechanical damage by impact, abrasion, nicks, and scratches, and 3) its ability to protect the substrate from corrosion in both the undamaged and mechanically damaged conditions. Susceptibility to thermal damage was evaluated with the remaining six specimens by exposing them to various heating cycles.

Figure 1 is a flow chart of the experimental operations used for the determination of coating properties. It summarizes the flow of specimens to the four types of evaluations: flexibility, corrosion protection (before and after mechanical damage), heat resistance, and properties after high- and low-temperature exposures. It shows that the twelve specimens obtained from each coated panel were distributed as follows: three for inherent flexibility, three for inherent corrosion-protecting properties, and six for cycled exposures to 650° F. The three specimens allotted to the inherent corrosion-protection evaluations (salt spray) were further subdivided so that one specimen was exposed in the undamaged condition, one damaged by three Rockwell-C hardness indentations, and the other damaged by an impact blow. The six specimens for heat exposure were divided into three pairs, one pair for each of the three different heating cycles shown (designated Series A, B, and C). Following these exposures, one of each pair was subjected to the flexibility evaluation and the other to salt spray. The flexibility and salt-spray evaluations were performed under the same conditions used to determine the inherent properties.

Techniques

Mechanical Damage – Mechanical damage was inflicted on two specimens from each coating prior to salt-spray exposure. One specimen was damaged by means of three Rockwell-C hardness indentations, spaced 1/2 in. apart on the longitudinal centerline at the middle of the specimen. The other specimen was subjected to a 4-ft-lb impact blow from an anvil of 1/8-in. radius and 1/2-in. length. Because of space restrictions in the impact machine, the specimens were located in a position that allowed one end of the anvil to strike first, thereby producing a wedge-shaped indentation in the specimen. The point of most severe impact was located 1.0 in. from one end of the specimen along the longitudinal centerline. Mechanical damage was evaluated from the results of the subsequent salt-spray exposure.

Thermal Damage – To simulate thermal exposures during SST service, six specimens of each coating were subjected to heating cycles. In Series A, two specimens from each coating were heated to 650° F in moving air in an electric furnace, held in the furnace for one hour, cooled in still air to room temperature, held at room temperature for at least

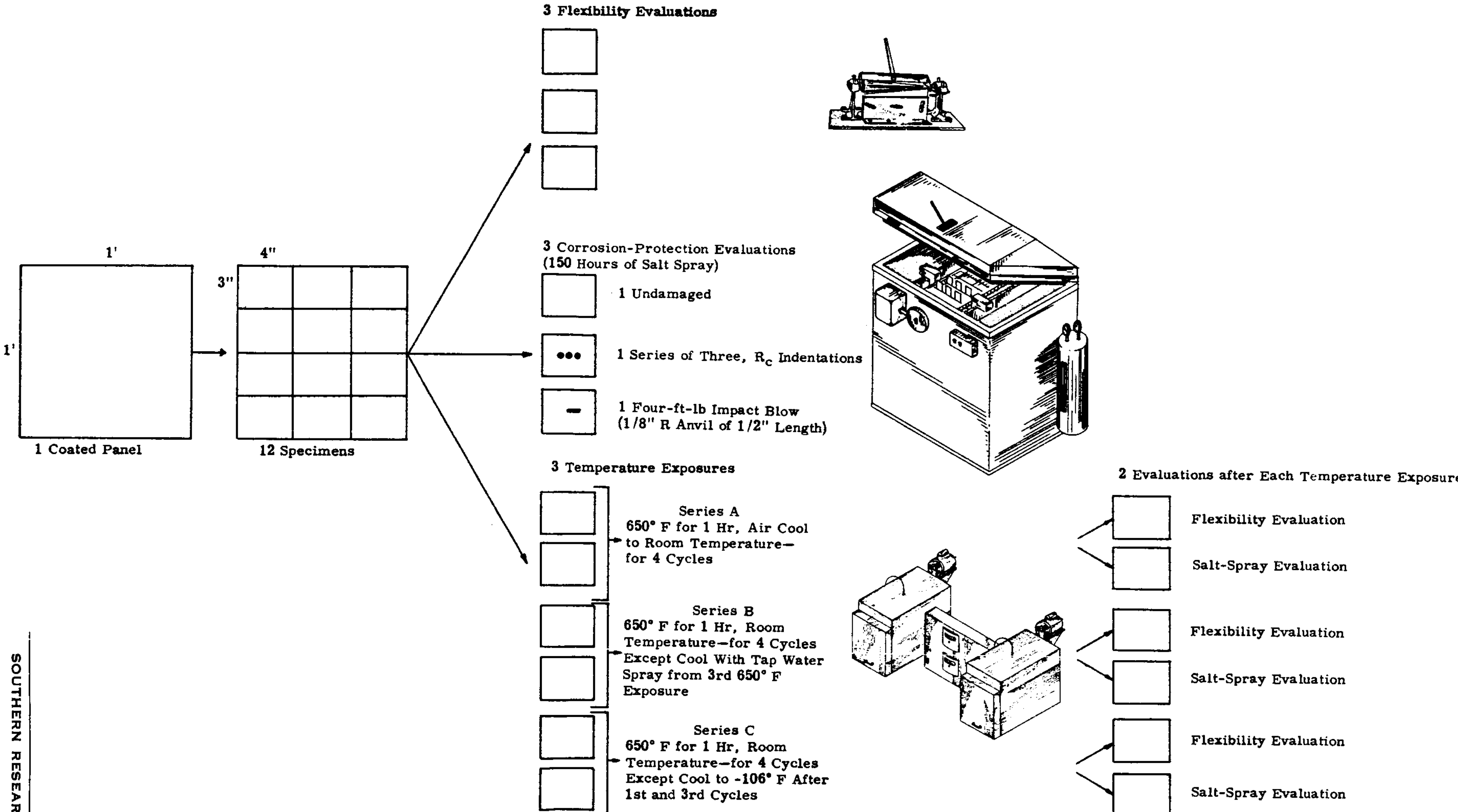


Figure 1. Flow chart of experimental operations.

one hour, and reheated again to 650° F for a total of four cycles. Two other specimens of each coating were heated in the same procedure used for Series A except that they were quenched from the third 650° F exposure by a tap-water spray to simulate service exposure of the hot skin to rain. This exposure series was designated as Series B. The two remaining specimens received the same Series A exposure except that after the first and third heating cycles they were cooled to room temperature and then exposed at -106° F for about 5 minutes. The low-temperature exposures consisted of submerging the specimens in a mixture of dry ice and methyl alcohol. This procedure was designated as Series C.

Bending (Flexibility) – ASTM Method D522 was used as a guide in making the flexibility determinations. In this method, specimens are bent 180° around a conical mandrel in the type of fixture depicted schematically in Figure 1. The conical mandrel is 8 in. long and ranges from 1/8-in. diameter at the small end to 1 1/2-in. diameter at the large end. The fixture is designed for use with low-strength substrates, and the cone is calibrated so that the smallest diameter over which the coating can be successfully bent is converted to an elongation reading.

Since the substrate used in these experiments was not the standard material for Method D522, some deviation from the method was necessary. When the first bends were made, it was found that the high yield strength of the maraging steel substrate was causing the small-diameter end of the mandrel to be damaged. Therefore, it was necessary to move the specimen location toward the large-diameter end of the cone to a position where one edge of the specimen was at the 1/2-in.-diameter location and the other edge at the 1-in.-diameter location. Because of these necessary deviations from the standard method, results were not converted to an elongation value but were used primarily for comparative purposes.

The bends were made by clamping one end of the specimen in the fixture, placing two talcum-coated pieces of brown Kraft paper between the specimen and the roller of the drawbar, and then rotating the drawbar to the opposite side of the fixture during a 15-second time interval. The dry-lubricated papers between the specimen and the roller prevented the surface of the coating from becoming so scored that coating failures would be obscured. The bent surface was visually examined while the specimen was in the fixture, and the distance between the 1/2-in.-diameter edge and the defect furthest from it were recorded. This distance was later converted to a diameter reading that indicated the sharpest bend radius that can be safely made with the coating in question.

Salt Spray — The determinations of corrosion protection were made by subjecting specimens to 150 hours of salt-spray exposure. ASTM Method B117 was used as a guide. The uncoated edges of all specimens were sealed with paraffin wax prior to their exposure. A filtered 20% solution of 99.95% sodium chloride was used in the reservoir of the salt-spray equipment. Wooden racks with a capacity for 60 specimens were designed and used to support the specimens at an angle of 5 degrees from vertical and spaced to prevent the condensate accumulated on one specimen from dripping on another. Conditions were controlled to maintain cabinet temperature between 92° F and 97° F, saturator-tower temperature between 100° F and 112° F, air pressure between 11.0 and 12.5 psi, rate of condensate collection within 0.5 to 3.0 cc/hr on a 10-cm diameter funnel, and pH of condensate between 5.75 and 7.00. Control checks were made daily while the cabinet was in operation, and the cabinet was conditioned before each run by allowing it to operate at least 24 hours without specimens. At the end of each run, the specimens were individually removed from the racks, rinsed in running tap water, placed top-side-up on paper towels, and allowed to dry. Results were determined by visual examination after the specimens had dried.

Evaluation Method

A basis for evaluating the experimental results with respect to service requirements was provided by exposing panels of Alclad 7075 Aluminum (a conventional aircraft skin material) to some of the same experimental conditions that were imposed upon the other coated specimens. Because there is no standard method for evaluating whether coatings will meet supersonic transport requirements, it was necessary to compare the properties of the coatings with each of the other coatings and with the properties of the conventional skin material.

The evaluations were made by reducing the results to a numerical value that indicated the relative worth of each coating with respect to a given property. Value ranges with larger numbers were assigned to those properties that were considered to be of greatest importance. Therefore, when all of the numerical values for a given coating were added, a total score was obtained that served to align the coatings in order of suitability for meeting SST requirements. In addition to the properties determined by experiment, the total score included values assigned to other characteristics of the coatings that affect their utility. These "practicality aspects," which were estimated from the best information available, consist of first cost, life expectancy under normal weathering, ease of application, ease of repair and maintenance in the field, effects of application temperature on the substrate, and present availability.

RESULTS AND DISCUSSION

Industrial-Survey Results

The mail survey resulted in 178 replies, many of which consisted only of letters explaining that the respondent was aware of no coatings that would meet the SST requirements shown on the questionnaire. The companies that replied are designated by an asterisk in Appendix A. From the replies that contained completed questionnaires or sufficient brochure information, suggestions for 44 coatings were obtained. Some of the coatings were suggested by more than one respondent, in which instances they were considered to be only one coating. Therefore, the 44 suggested coatings represent different types rather than only different brand names.

The numerical rating system used to evaluate the suggested coatings is illustrated in Table I. In constructing this system, all of the questionnaire information that was not already expressed as "good," "fair," or "poor" was changed to such expressions by means of the conversions shown in the footnotes of Table I. The numerical values assigned to these expressions were devised so that the properties considered most important for SST service would have higher values than those considered less important.

Each type of coating for which a completed questionnaire was returned, or which was considered because of information found in the literature, was rated by this system. A total score for each coating was obtained by adding the rating values for each property. The scores served the purpose of indicating which of the coatings were most promising in comparison with all of the others; the coatings with the higher scores being considered to be the most promising. The scores were also used to establish the standing of each coating within its own category (metallic, organic, etc.). These category standings were designated by consecutive numbers; 1 being the most promising, 2 the next, etc. The detailed ratings, scores, and standings for each of the 44 coatings are presented in Appendix C.

The 22 coatings chosen for experimental evaluation are listed in Table II. This table shows the identification numbers assigned to each coating, the categories in which the coatings were grouped, the types of coating, the scores resulting from the rating system, the standings of the coatings within their categories, the trade names, and the suppliers of the experimental samples. Although the scores were used as a guide in selecting the coatings for experimentation, they were not chosen on the basis

Table I

Numerical Rating System for Industrial-Survey Results

Property	Assigned Values[1] Good	Fair	Poor
Corrosion Protection in Normal Weather	50	25	0
Maximum Service Temperature[2]	40	20	0
Resistance to Thermal Fluctuations	30	15	0
Flexibility at 650° F	30	15	0
Flexibility at Ambient Temperatures	30	15	0
Minimum Service Temperature[3]	20	10	0
Flexibility at -100° F	20	10	0
Resistance to Abrasion, etc.	10	5	0
Ease of Field Application[4]	10	5	0
Application Cost[5]	10	5	0
Availability[6]	6	3	-

[1] Numerical values were assigned to each coating property according to their estimated order of importance for SST application.
[2] Good: 600° F and above, Fair: 400 to 600° F, Poor: 400° F and below.
[3] Good: -65° F and below, Fair: -25 to -65° F, Poor: -25° F and above.
[4] Estimated in accordance with the application procedure reported in questionnaires or brochures.
[5] Determined on the basis of cost per square foot of surface covered; Good: $1.00 or less, Fair: $1.00 to $5.00, Poor: $5.00 and above.
[6] Good: Production item, Fair: Development item.

Table II

Coatings Selected for Experimental Evaluation by Use of the Industrial Survey Rating System

No.	Category	Type of Coating	Score	Category Standing	Trade Name of Coating	Supplier
11	Metallic	Cold-Galvanized	256	1	Rust-Ban 191	Humble Oil & Refining Co.
7	Metallic	Electroplated & Hot-Rolled Nickel	238	4	Hot-Rolled Ni Coating	The International Nickel Co., Inc.
1	Metallic	Electrophoretic & Rolled Aluminum[1]	238	4	Elphal Process	The British Iron & Steel Research Asso.
8	Metallic	Electroplated Nickel & Cadmium	236	5	Diffused Ni-Cd	The Boeing Co., MASD, Power Plating Co.[2]
3	Metallic	Vacuum-Deposited Aluminum	233	6	Vapor-Deposited Aluminum	Ethyl Corp.
2	Metallic	Flame-Sprayed Aluminum	226	8	Flame Sprayed Aluminum (99.0%)	Metco, Inc.
4	Metallic	Diffused Aluminum Iron	216	9	Haynes Diffusion Coating No. C-10	Haynes-Stellite Co.
12	Metallic	Hot-Dip Galvanized Zinc	206	10	Hot-Dip Galvanized (Zinc)	Metal Coating Corp.
9	Metallic	Electroless Nickel Alloy	161	11	Kanigen Nickel Alloy	General American Transportation Corporation
16	Organic	Thermosetting Polymer	236	1	GIC-805	The National Glaco Chemical Co.
19	Organic	Silicone-Resin Vehicle	226	2	Vita-Var No. 16169 Heat Absorption Paint White Formulation PV100X	Vita-Var Company
20	Organic	Teflon in Silicone Resin	216	3	EC-1697E (PTFE in Silicone Resin)	Acheson Colloids Co.
18	Organic	Catalytically Cured Silicone	211	4	Catalytically Cured Silicone Coating	ASD (ASRCNE-2)
17	Organic	Aluminum-Modified Silicone	178	5	XP-310 Heat-Resistant Al Paint	Dow Corning Corp.
21	Semi-Organic	Silicon-Nitrogen Polymer	213	1	Hexaphenylcyclotrisilazane-Ethylenediamine Silazane Polymer Blend	Southern Research Institute
25	Inorganic	Fused Minerals	246	1	Korok A-19	The Enamel Products Co.
24	Inorganic	Flame-Sprayed Aluminum Oxide	226	2	Rokide A Aluminum Oxide	Norton Co., C. M. C. Corp
27	Inorganic	Zinc Silicate	211	3	ZRAS	Koppers Co., Inc.
30	Other	---	246	1	Heat-Resistant Coating 57X 50	Benjamin Foster Co.
32	Other	---	246	1	Markal Protective Coating "DA-9" Aluminum	Markal Co.
33	Other	---	221	3	"Pyre-M.L." Varnish	E. I. duPont de Nemours & Co. Inc. Marshall Laboratory
28	Other	---	196	5	A-61110-50 Aircraft White	Rust-Oleum Corp.

[1] Because of manufacturing considerations, the coating was applied to a mild steel substrate.
[2] Recommended by Boeing. Coating was applied by Power Plating Company and heat-treated at Southern Research Institute.

of score alone. Consideration was given to obtaining adequate representation from each of the coating categories because it was thought that manufacturers from widely different fields (paint manufacturers compared to electroplaters, for example) might have different conceptions of the adequacy of some of the properties. Other factors such as the cost and availability of samples, the degree of uncertainty in applying the rating system, the confidence held in the accuracy of suppliers' literature, and previous inclusion of similar coatings also had an influence on the choices made. All coatings with an identification number greater than 36 were excluded from the experiments, regardless of their standing, because information on the coating was received too late for it to be included.

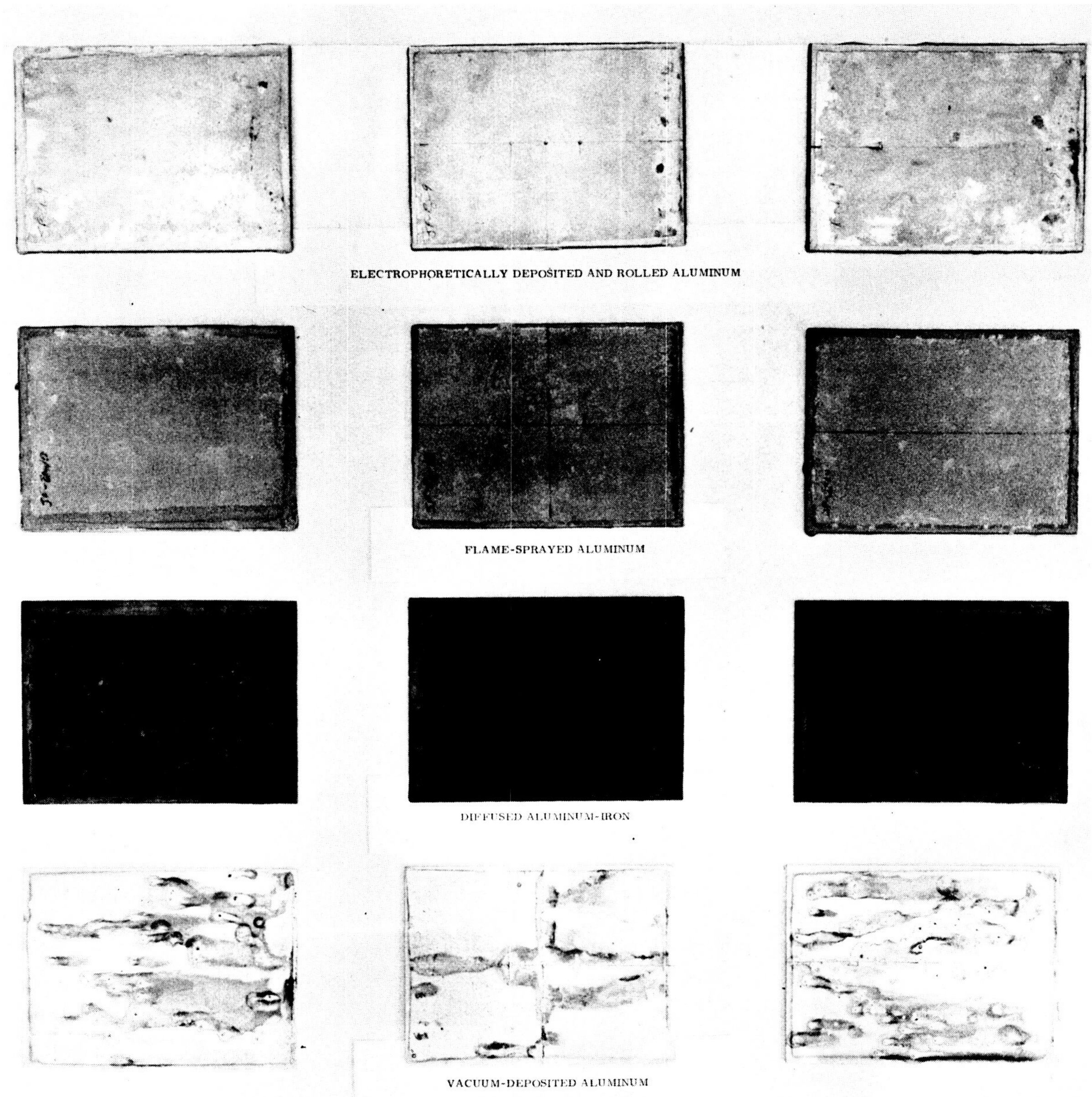
A brief description of each of the coatings listed in Table II was given previously in the PROCEDURE section of this report.

Experimental Results

The results of salt-spray exposure before and after mechanical damage are pictured in Figures 2 through 7. In these figures, the undamaged specimens are located on the left, the specimens damaged by three Rockwell-C indentations are located at the center, and the specimens damaged by a 4-ft-lb impact blow are located on the right.

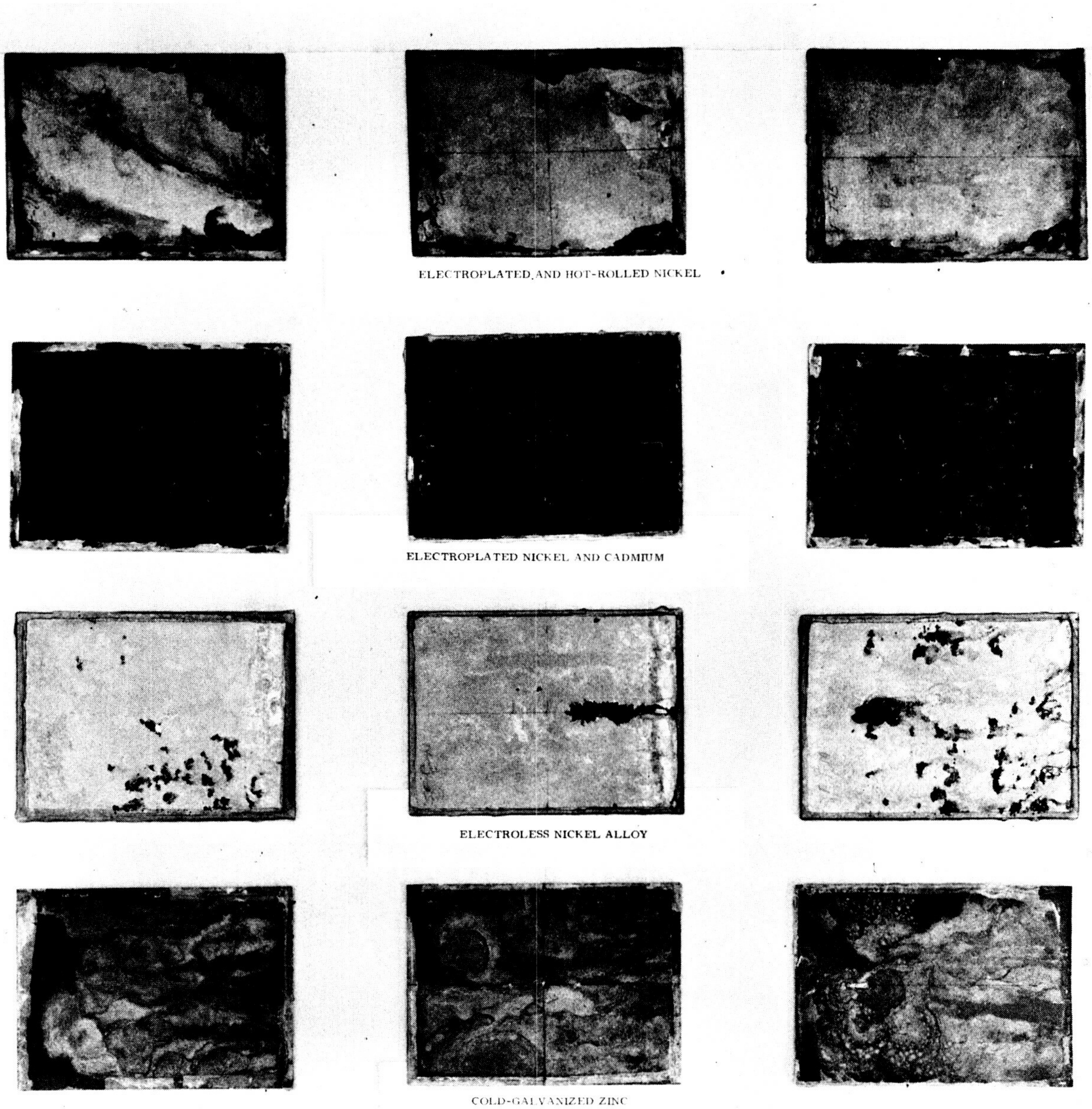
As shown in Figure 2, both the Electrophoretically Deposited and Rolled Aluminum (Elphal) and the Flame-Sprayed Aluminum coatings show some discoloration and moderate deposits which are minor corrosion products of the aluminum itself. No substrate corrosion occurred. The Diffused Aluminum-Iron coating allowed the substrate to rust completely. The Vacuum-Deposited Aluminum coatings allowed the substrate to rust considerably. The undamaged and the R_c-damaged specimens show 50 to 75% substrate corrosion and the impact-damaged specimen shows 75 to 100%.

In Figure 3, the Electroplated and Hot-Rolled Nickel coating shows considerable discoloration but no corrosion of the substrate except at the edges. The edge corrosion was ignored because it was considered to be caused by the failure of the paraffin seal. Some discoloration was present in the coating prior to salt-spray exposure but the post-exposure staining is considerably greater. Although the Electroplated Nickel and Cadmium coating protected the substrate from corrosion, dark discolorations and moderately heavy deposits of its own corrosion products developed. This coating had less extreme dark discolorations prior to exposure. The Electroless Nickel alloy, which had a glossy metallic color prior to exposure, developed dulling discolorations and allowed corrosion of the substrate to take place, particularly at mechanically damaged locations.



RESULTS OF SALT SPRAY EXPOSURE

Figure 2. Appearance of electrophoretically deposited aluminum, flame-sprayed aluminum, diffused aluminum-iron, and vacuum-deposited aluminum after 150 hours salt spray in the undamaged and mechanically damaged conditions.



RESULTS OF SALT SPRAY EXPOSURE

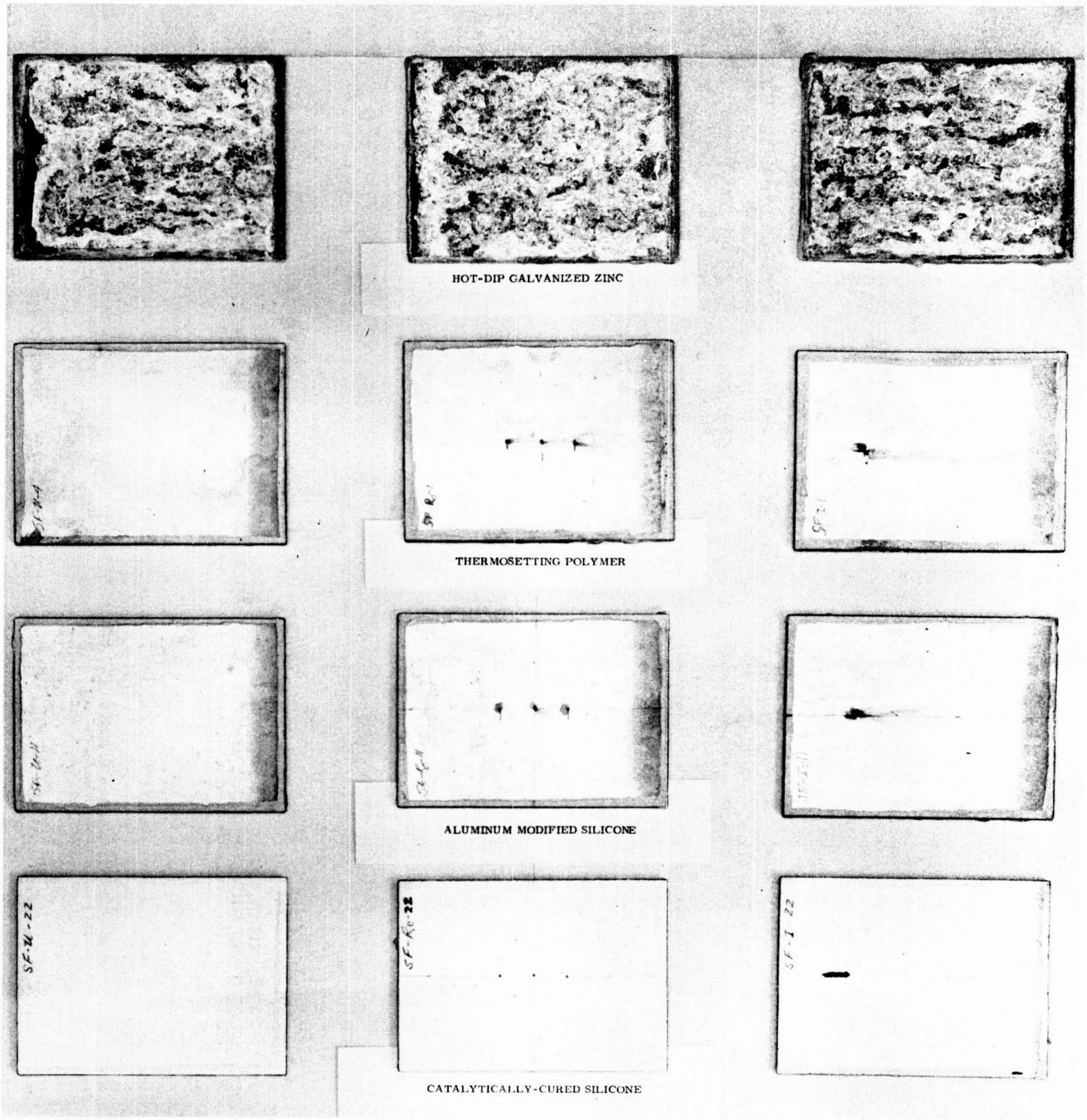
Figure 3. Appearance of electroplated and hot-rolled nickel, electroplated nickel and cadmium, electroless nickel alloy, and cold-galvanized zinc after 150 hours salt spray in the undamaged and mechanically damaged conditions.

The Cold-Galvanized Zinc coating completely protected the substrate but formed moderately heavy discolorations from its own corrosion. The coating was dull gray in appearance prior to exposure.

In Figure 4, the Hot-Dip Galvanized coating, which had the conventional spangled metallic surface prior to exposure, sacrificially corroded to form heavy deposits. It provided complete protection for the substrate, however. The heavy corrosion of the Hot-Dip Galvanized Zinc compared to the Cold-Galvanized Zinc shown in Figure 3 indicates that the bonding agent in the Cold-Galvanized Zinc is effective in decreasing the rate of corrosion of the coating. The Thermosetting Polymer and the Aluminum-Modified Silicone developed light stains but protected the substrate except at locations of mechanical damage. The Catalytically Cured Silicone remained essentially unchanged in the undamaged condition and, although rust developed at the locations of mechanical damage, the lack of stains running from the damaged spots indicates that the substrate corrosion was slight.

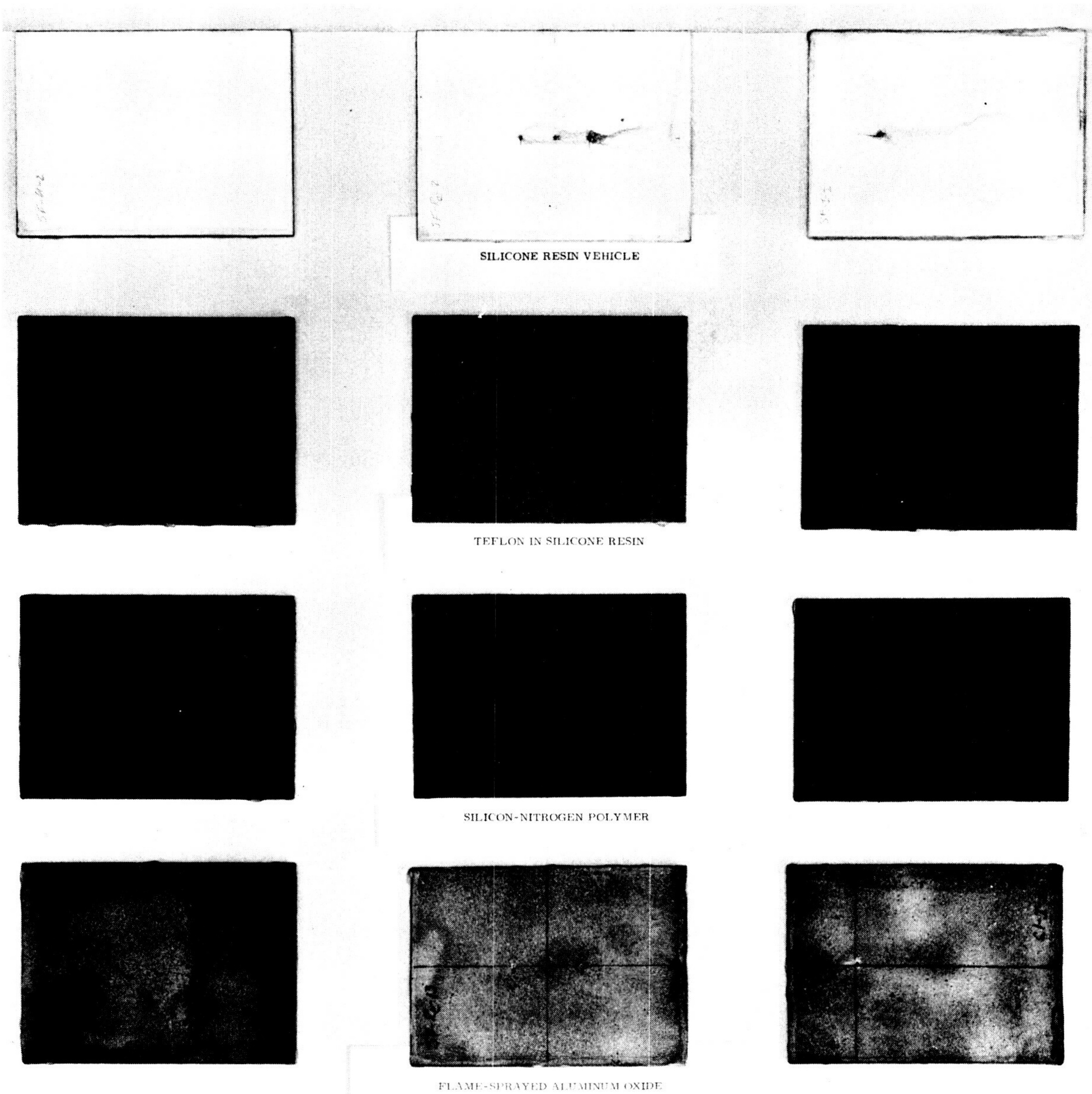
In Figure 5, the performance of the Silicone-Resin Vehicle was similar to that of the Catalytically Cured Silicone except that heavier corrosion occurred at the locations of mechanical damage. The Teflon in Silicone resin, an inherently dark coating, was essentially unchanged by the salt-spray exposure except for rust that formed in the mechanically damaged locations. The dark stains that show through the coating were present before exposure. The white stains on the surface of the coating are salt stains. The Silicon-Nitrogen Polymer, also an inherently dark coating, allowed the substrate to rust in both damaged and undamaged locations. The results from the Flame-Sprayed Aluminum Oxide were erratic. The undamaged specimen exhibited a myriad of small rust spots but no large corroded areas or runs of rust. In contrast, the undamaged portions of the mechanically damaged specimens contained only a few scattered spots of corrosion. Rust appeared in the R_c-damaged locations but did not in the 4-ft-lb impact location.

In Figure 6, the Fused-Minerals coating, a black coating with small white spots prior to exposure, permitted the substrate in the undamaged specimen to rust over approximately 25% of the surface area. Heavy corrosion and rust flows occurred at the locations of mechanical damage. The Zinc-Silicate coating discolored similarly to the Cold-Galvanized Zinc shown in Figure 3 and protected the substrate from corrosion. The A-61110-50 coating provided good protection but did allow a few small spots of rust to form in all three specimens. Some of these spots are visible in the photograph but the high reflectance of the coating tends to obscure them. The shadowy areas on the undamaged



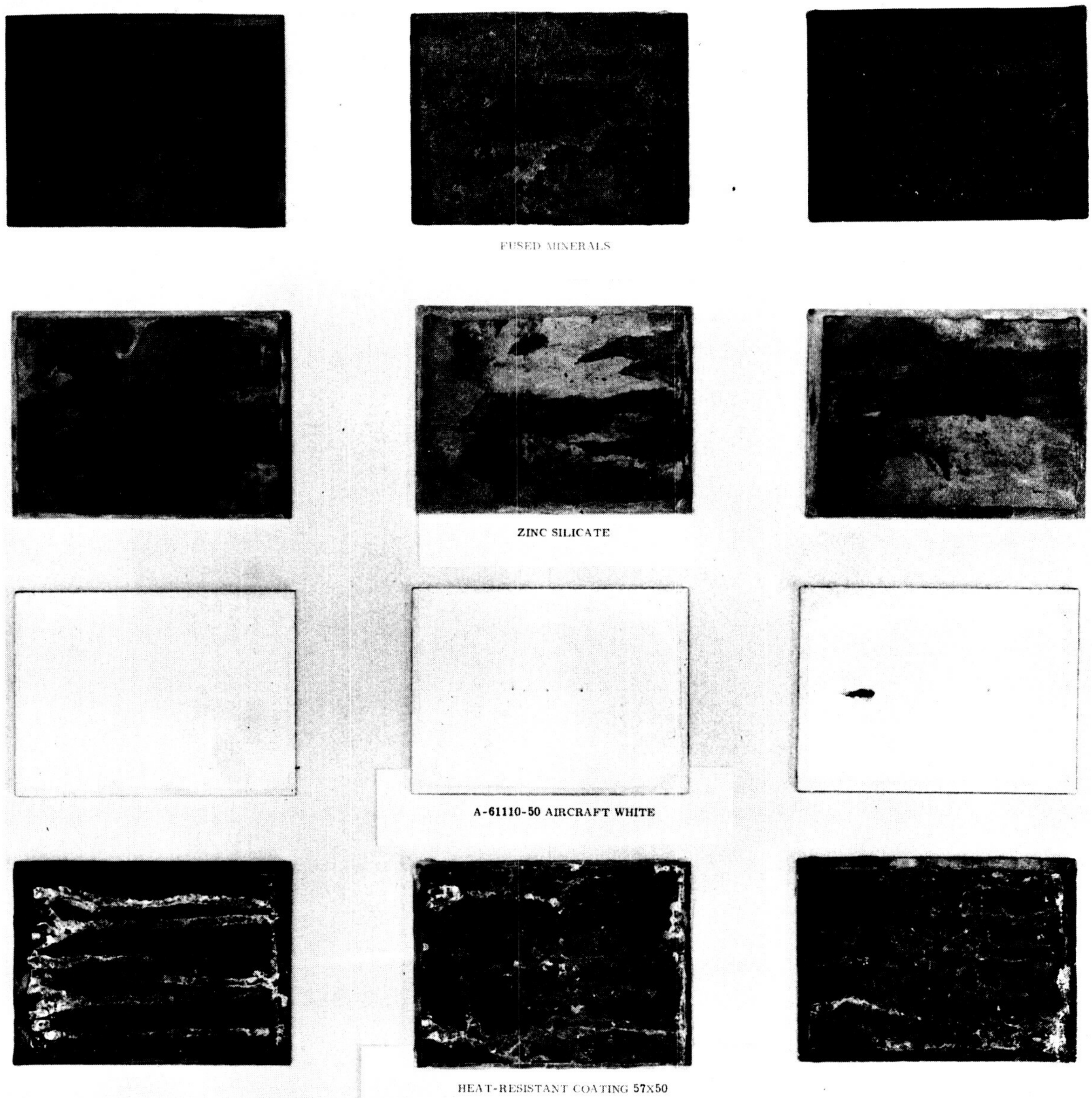
RESULTS OF SALT SPRAY EXPOSURE

Figure 4. Appearance of hot-dip galvanized zinc, thermosetting polymer, aluminum modified silicone, and catalytically cured silicone after 150 hours salt spray in the undamaged and mechanically damaged conditions.



RESULTS OF SALT SPRAY EXPOSURE

Figure 5. Appearance of silicone-resin vehicle, Teflon-in-silicone resin, silicon-nitrogen polymer, and flame-sprayed aluminum oxide after 150 hours salt spray in the undamaged and mechanically damaged conditions.



RESULTS OF SALT SPRAY EXPOSURE

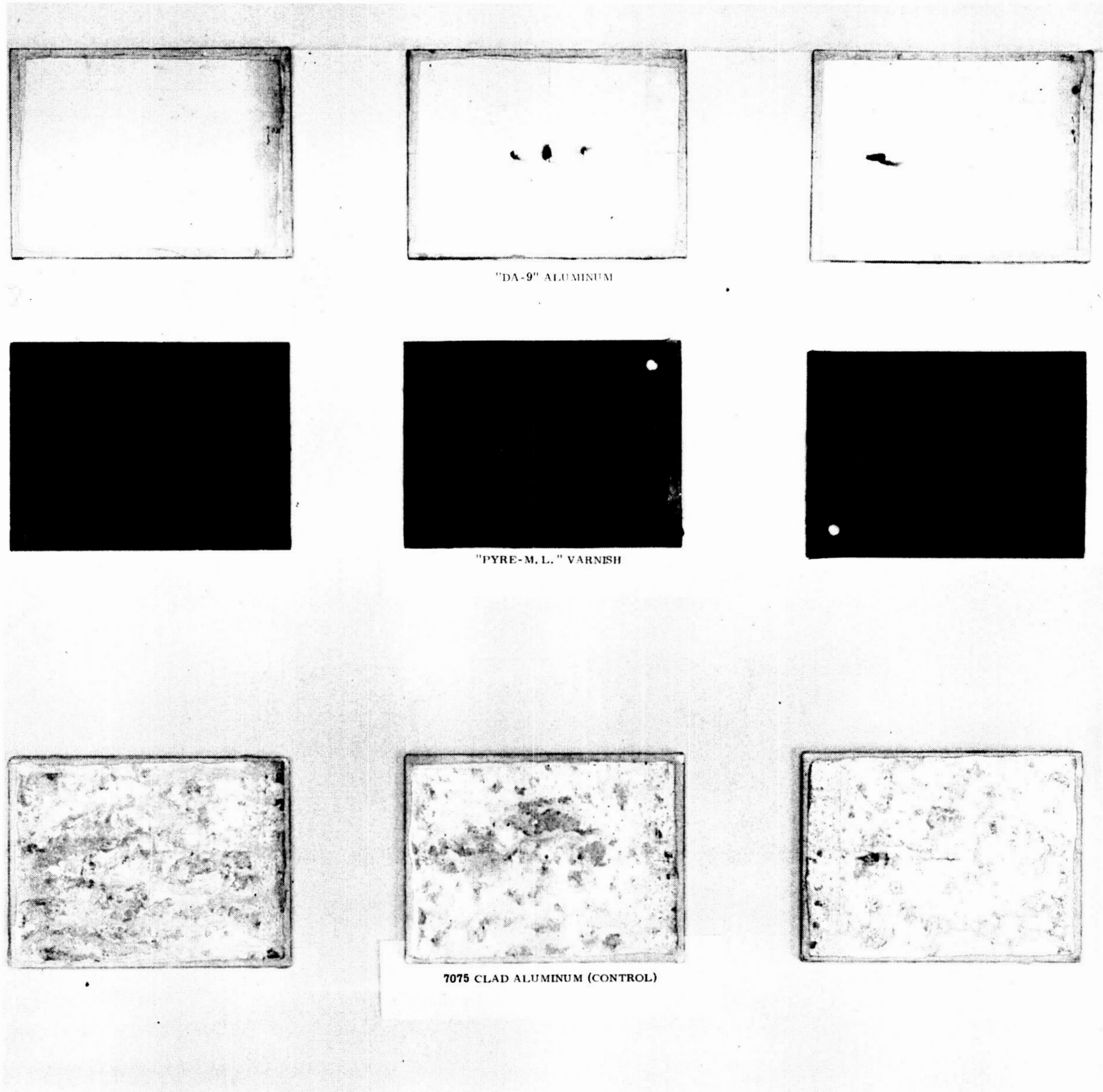
Figure 6. Appearance of fused minerals, zinc silicate, A-61110-50 (aircraft white), and heat-resistant coating 57X50 after 150 hours salt spray in the undamaged and mechanically damaged conditions.

specimen were externally caused. Rust formed in the damaged locations but did not run. Heat-Resistant Coating 57X50 protected the substrate from corrosion, but white streaks of corrosion product from the coating formed over 50% of the surface area of all three specimens. This coating was dark in color prior to the salt-spray exposure.

The remaining two coatings and the control specimens are shown in Figure 7. The "DA-9" Aluminum coating stained to some extent but protected the substrate of the undamaged specimen. However, heavy corrosion and rust runs occurred in the damaged locations. The "Pyre-M. L." Varnish coating appears dark in the photograph because of its amber color. Although discolorations formed during the salt-spray exposures, the substrate was protected from rusting except at the locations of mechanical damage. The round holes in the corner of the two mechanically damaged specimens were used to support the panel when the coating was applied. The 7075 Alclad aluminum control panel discolored considerably and produced moderate deposits of aluminum corrosion. This amount of corrosion on the material that is successfully used on conventional aircraft is an indication that the salt-spray exposures were quite severe. Therefore, those specimens that corroded less than or similarly to the 7075 Alclad aluminum panels can be expected to provide promising corrosion protection in service.

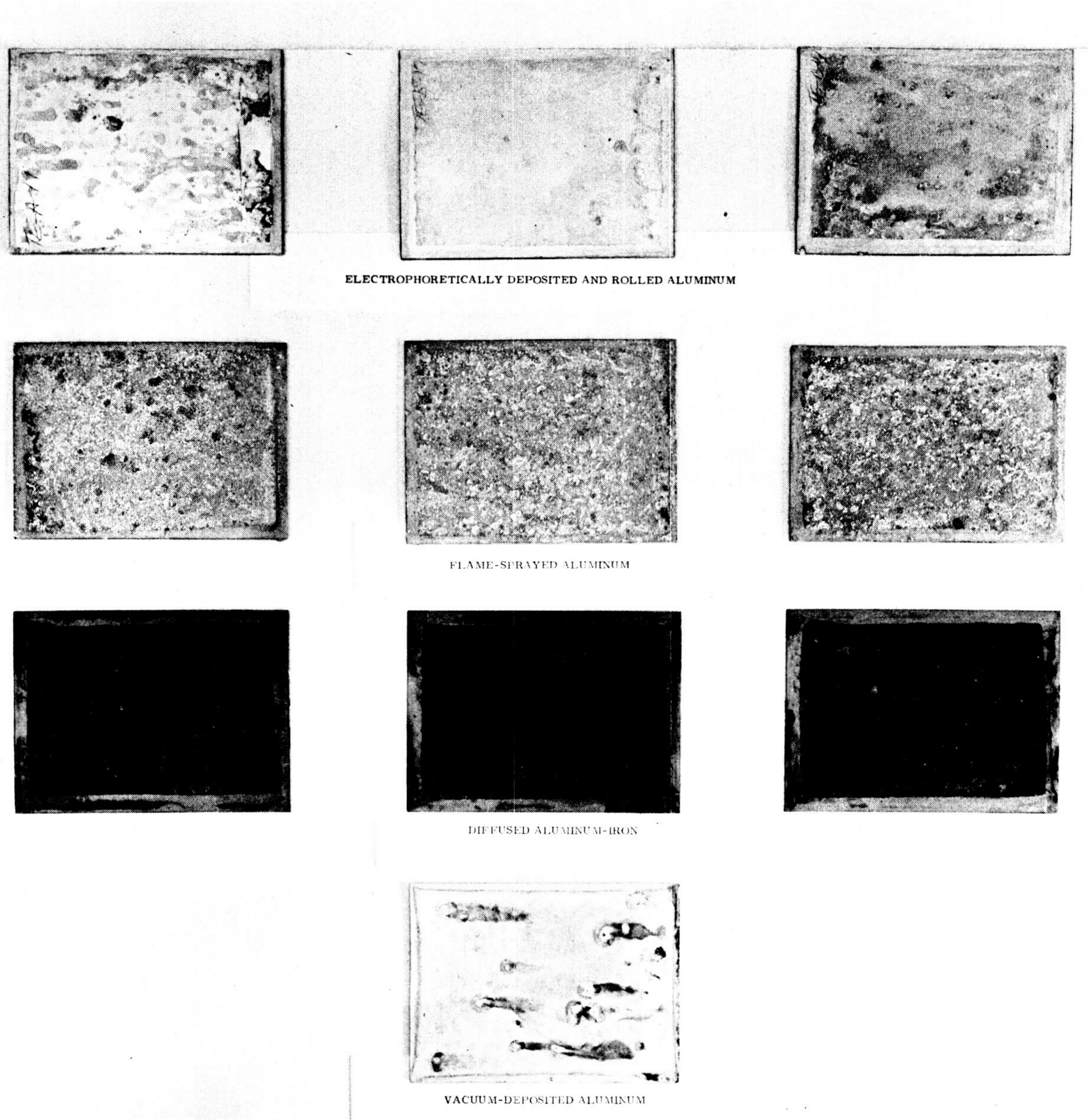
The results from the salt-spray exposures of the specimens exposed to the Series A, B, and C cyclic heating to 650° F are pictured in Figures 8 through 13. In these figures, the specimens are positioned so that the Series A specimens (exposed to simple thermal cycling) are on the left, the Series B specimens (quenched from 650° F with water spray) in the middle, and the Series C specimens (cooled to -106° F) on the right. The coatings are arranged in the same sequence used in Figures 2 through 7.

The first two coatings shown in Figure 8, the Electrophoretically Deposited and Rolled Aluminum and the Flame-Sprayed Aluminum, protected the substrate from corrosion but the amount of discoloration and aluminum corrosion deposits are greater than those of the unheated coatings shown in Figure 2. The completely corroded substrate of the Diffused Aluminum-Iron and the considerable substrate corrosion of the Vacuum-Deposited Aluminum are very similar to the condition of the unheated specimens. Only one Vacuum-Deposited Aluminum specimen was available because the supplier of this coating could not furnish a full set of specimens within the time and funds available for these experiments.



RESULTS OF SALT SPRAY EXPOSURE

Figure 7. Appearance of "DA-9" aluminum, "Pyre-M. L." varnish, and the 7075 clad aluminum control specimen after 150 hours salt spray in the undamaged and mechanically damaged conditions.



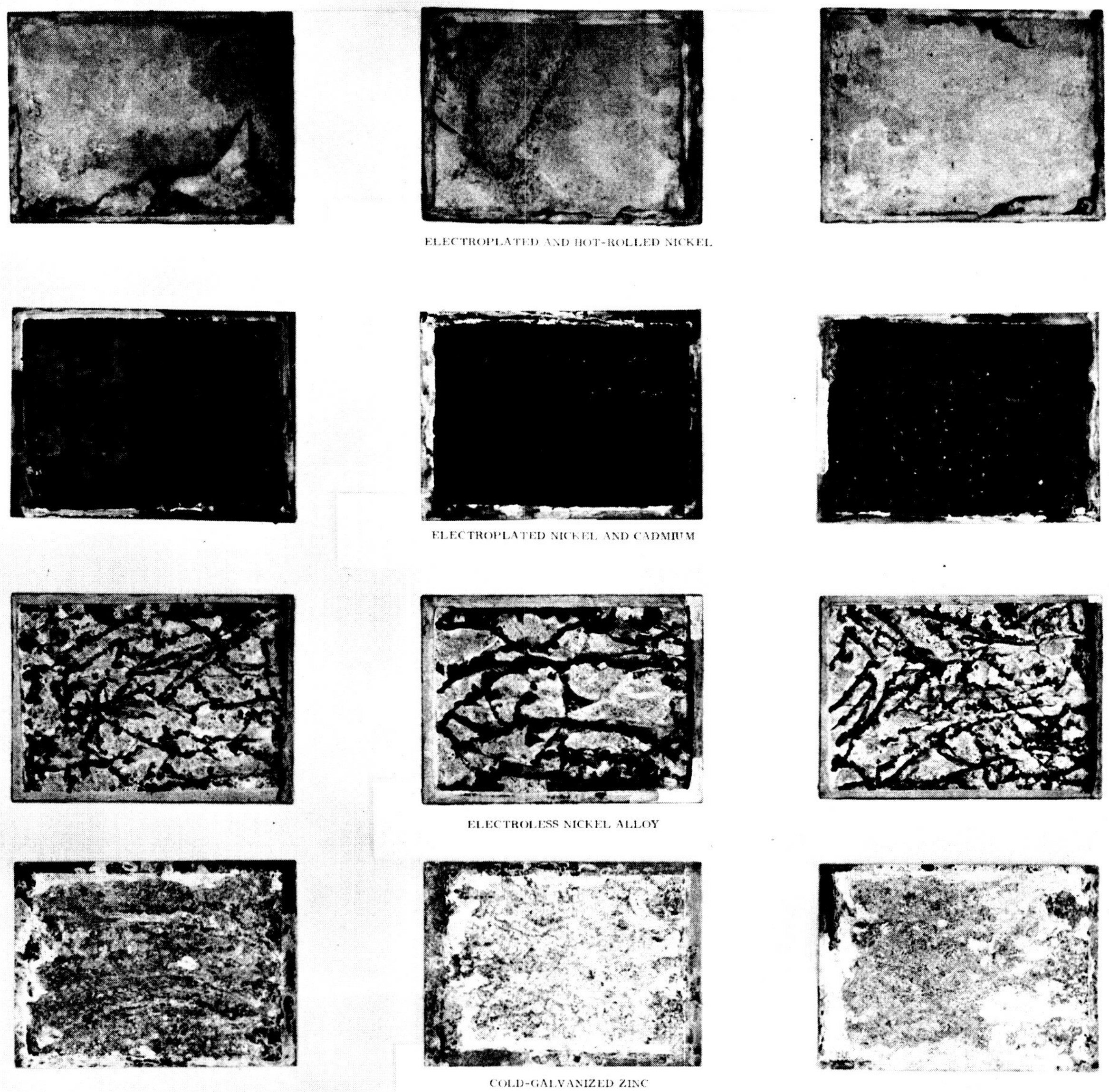
RESULTS OF SALT SPRAY EXPOSURE

Figure 8. Appearance of electrophoretically deposited and rolled aluminum, flame-sprayed aluminum, diffused aluminum-iron, and vacuum-deposited aluminum after 150 hours salt spray in the thermally damaged conditions.

In Figure 9, the Electroplated and Hot-Rolled Nickel developed discolorations similar to those developed by the unheated specimens shown in Figure 3, indicating that this coating was unaffected by the heat exposures. The specimens coated with Electroplated Nickel and Cadmium developed darker discolorations during the heat exposures but the coating appears to have protected the substrate similarly to the unheated specimens. The Electroless Nickel alloy coating allowed considerably more substrate corrosion to occur after exposure to the heating cycles. The pattern of corrosion indicates that the thermal exposures produced cracks in this coating. Although the Cold-Galvanized Zinc continued to protect the substrate after exposure to heating cycles, there was a considerable increase in the amount of sacrificial self-corrosion of the zinc. The heavy corrosion deposits are similar to those that formed on the unheated Hot-Dip Zinc specimens (Figure 4). These characteristics show that the protective influence of the bonding agent in the Cold-Galvanized coating is essentially destroyed by the heat exposures.

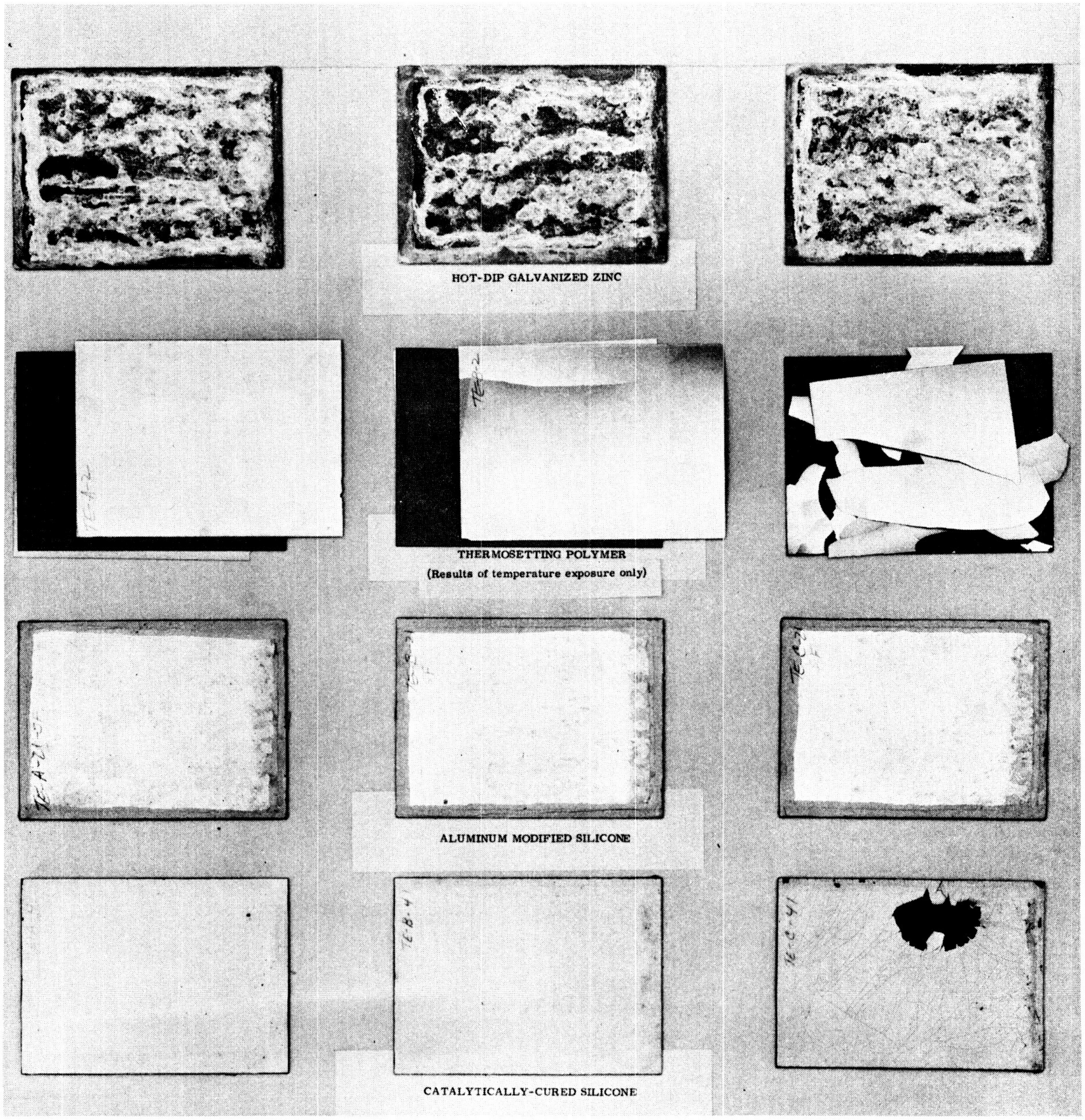
The first coating in Figure 10, Hot-Dip Galvanized Zinc, sacrificially protected the substrate and produced heavy deposits similar to those on the unheated specimens (Figure 4). The coating was apparently unaffected by the heat exposures. The Thermosetting Polymer completely separated from the substrate during each of the heat exposures and, therefore, was not subjected to salt spray. The Aluminum-Modified Silicone was apparently unaffected by the heat exposures and, although it discolored slightly, it completely protected the substrate. The Catalytically Cured Silicone withstood the Series A and B cycles and provided complete protection for the substrate. The -106° F temperature in the Series C cycles, however, caused the coating to crack extensively and partially spall off of the substrate. During the subsequent salt-spray exposure, rusting of the substrate occurred only in the area from which the coating had spalled. No rusting occurred in the cracks, indicating that the primer for this coating also provided good protection for the substrate.

In Figure 11, the Silicone Resin Vehicle discolored considerably during the Series A exposure and permitted extensive corrosion to occur in the substrate. The Series B and C exposures caused this coating to separate from the substrate, so the specimens were not subjected to salt spray. The Teflon in Silicone Resin remained undamaged by the heat exposures and protected the substrate from corrosion except at some of the locations where identification numbers had been applied with an ordinary lead pencil. The damage inflicted by the pencil marks provides an indication of the softness of this coating. The Silicon-Nitrogen Polymer permitted the substrate to rust considerably, but since the corrosion was comparable to that in the unheated specimens (Figure 5), it may be assumed that the coating was not



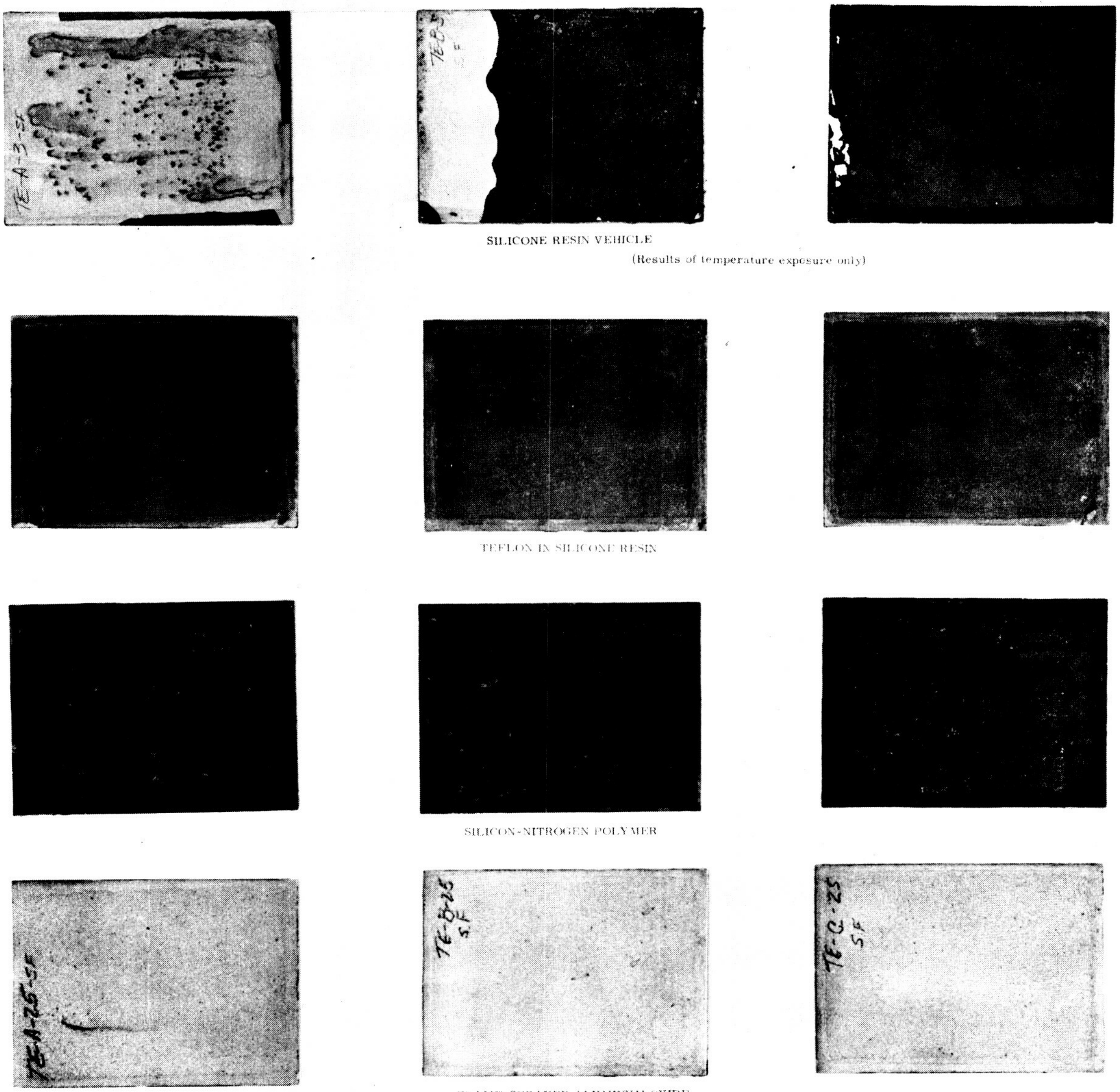
RESULTS OF SALT SPRAY EXPOSURE

Figure 9. Appearance of electroplated and hot-rolled nickel, electroplated nickel and cadmium, electroless nickel alloy, and cold-galvanized zinc after 150 hours salt spray in the thermally damaged conditions.



RESULTS OF SALT SPRAY EXPOSURE

Figure 10. Appearance of hot-dip galvanized zinc, thermosetting polymer, aluminum-modified silicone, and catalytically cured silicone after 150 hours salt spray in the thermally damaged conditions.



RESULTS OF SALT SPRAY EXPOSURE

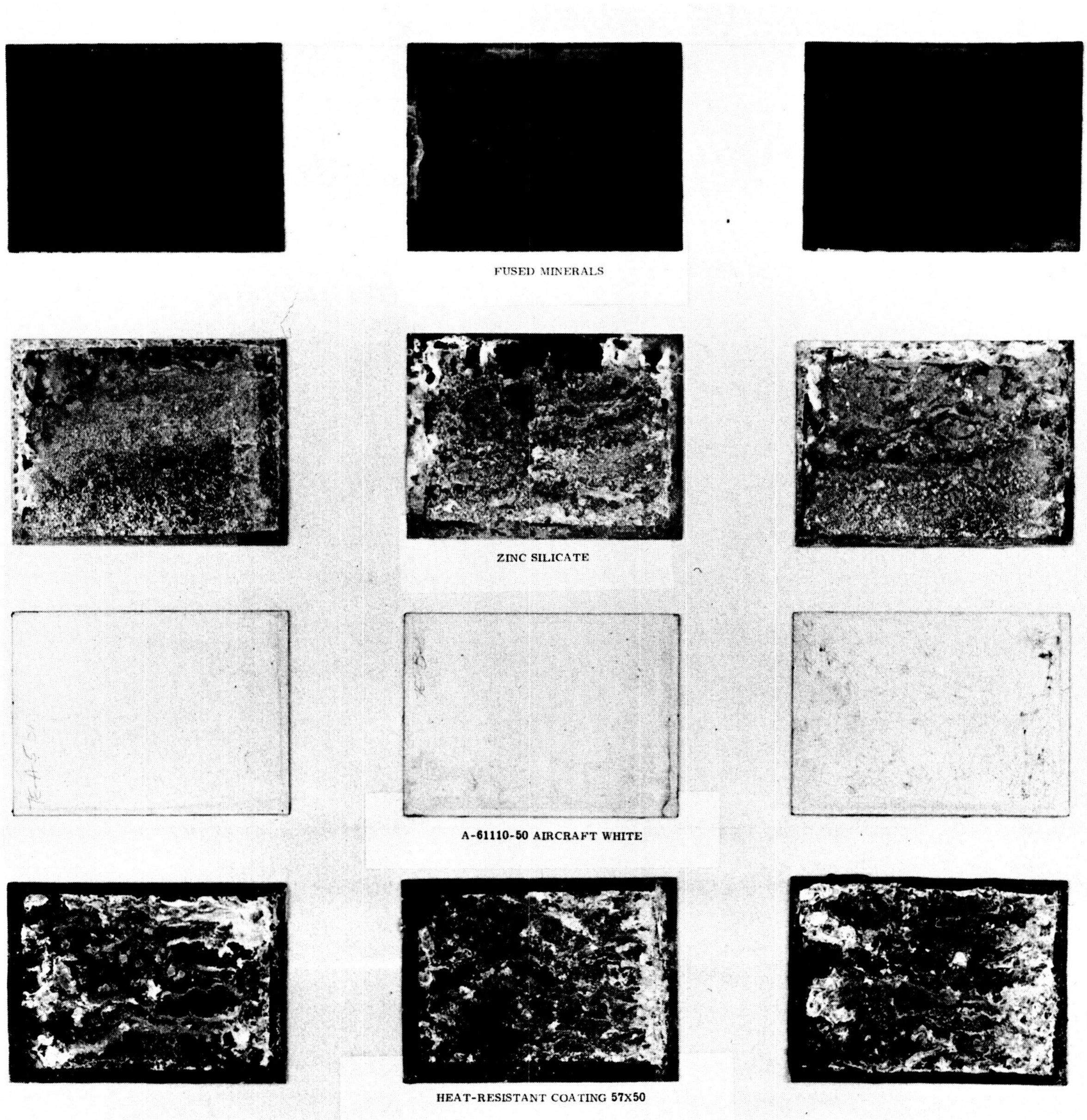
Figure 11. Appearance of silicone-resin vehicle, Teflon in silicone resin, silicon-nitrogen polymer, and flame-sprayed aluminum oxide after 150 hours salt spray in the thermally damaged conditions.

damaged by the heat exposures. The Flame-Sprayed Aluminum Oxide, with the exception of a single rust run in the specimen from Series A, provided good protection to the substrate. In fact, the slight amount of point corrosion in the heated specimens compared to the amount in the unheated specimens in Figure 5 indicates that the heat exposures were beneficial to this coating.

In Figure 12, the Fused-Minerals coating permitted the substrate to rust to essentially the same extent as the unheated coatings shown in Figure 6. The heat-exposed Zinc Silicate continued to protect the substrate by sacrificial corrosion of the zinc. However, the heavy corrosion deposits on these specimens compared to the discoloration produced in the unheated specimens (Figure 6) show that the heat exposures have destroyed the ability of the bonding agent to decrease the rate of zinc corrosion. Coating A-61110-50 Aircraft White exhibited reduced corrosion protection after the heat exposures. The specimen from Series A permitted a moderate amount of point corrosion, and the specimen from Series B produced shadowy rust areas in addition to the point corrosion. Exposure to Series C caused the coating to crack extensively, resulting in considerable point corrosion. Heat-Resistant Coating 57X50 continued to protect the substrate after the heat exposures, but comparison with the unheated specimens in Figure 6 shows that the amount of white deposits from the corrosion of the coating increased considerably.

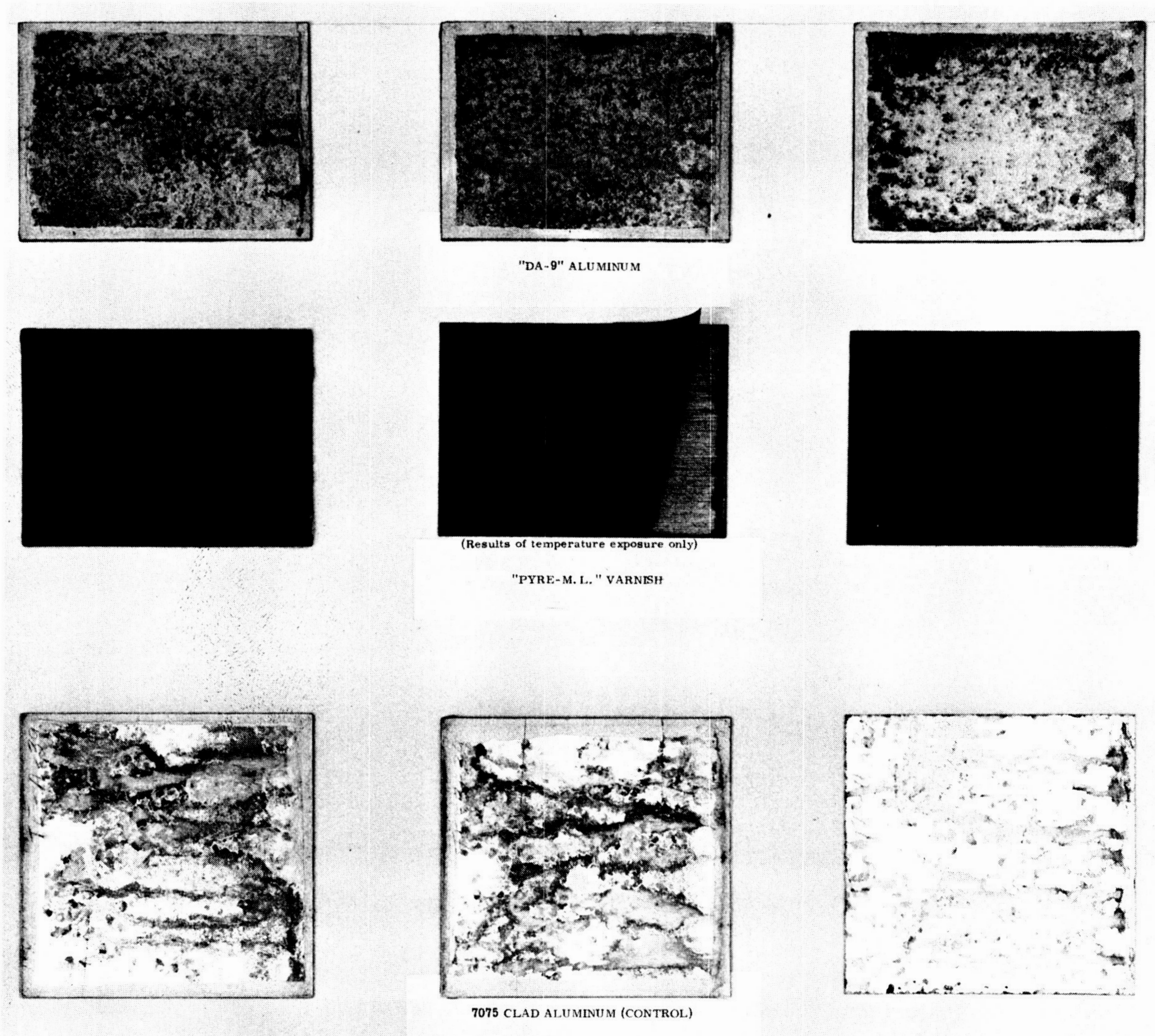
The remaining heat-exposed salt-spray specimens are shown in Figure 13. The "DA-9" Aluminum coating deteriorated badly in the heat exposures and permitted extensive corrosion to occur in the substrate. Although "Pyre M. L." Varnish allowed discolorations to form, it protected the substrate from corrosion after subjection to the Series A and Series C exposures. The thermal shock inflicted in the Series B exposures, however, caused the coating to partially peel from the substrate. The heat-exposed 7075 Alclad aluminum control specimens produced increased discoloration and corrosion deposits compared to the unexposed specimens in Figure 7. Of course, this alloy was not designed to withstand such temperature exposures and, therefore, direct comparisons with the results from the coatings are not necessarily valid.

The appearance of the flexibility specimens after bending are pictured in Figures 14 through 19. In these figures the specimens are arranged from left to right showing one of the three inherent-flexibility specimens and each of the flexibility specimens that had been exposed to the Series A, B, and C heating cycles. In addition to showing the flexibility of the coatings before and after heat exposures, these specimens can also be used to indicate the visible effects of the heating cycles alone by comparisons of the unbent portions of the heated specimens with the unbent portion of the inherent-flexibility specimen.



RESULTS OF SALT SPRAY EXPOSURE

Figure 12. Appearance of fused minerals, zinc silicate, A-61110-50 aircraft white, and heat-resistant coating 57X50 after 150 hours salt spray in the thermally damaged conditions.



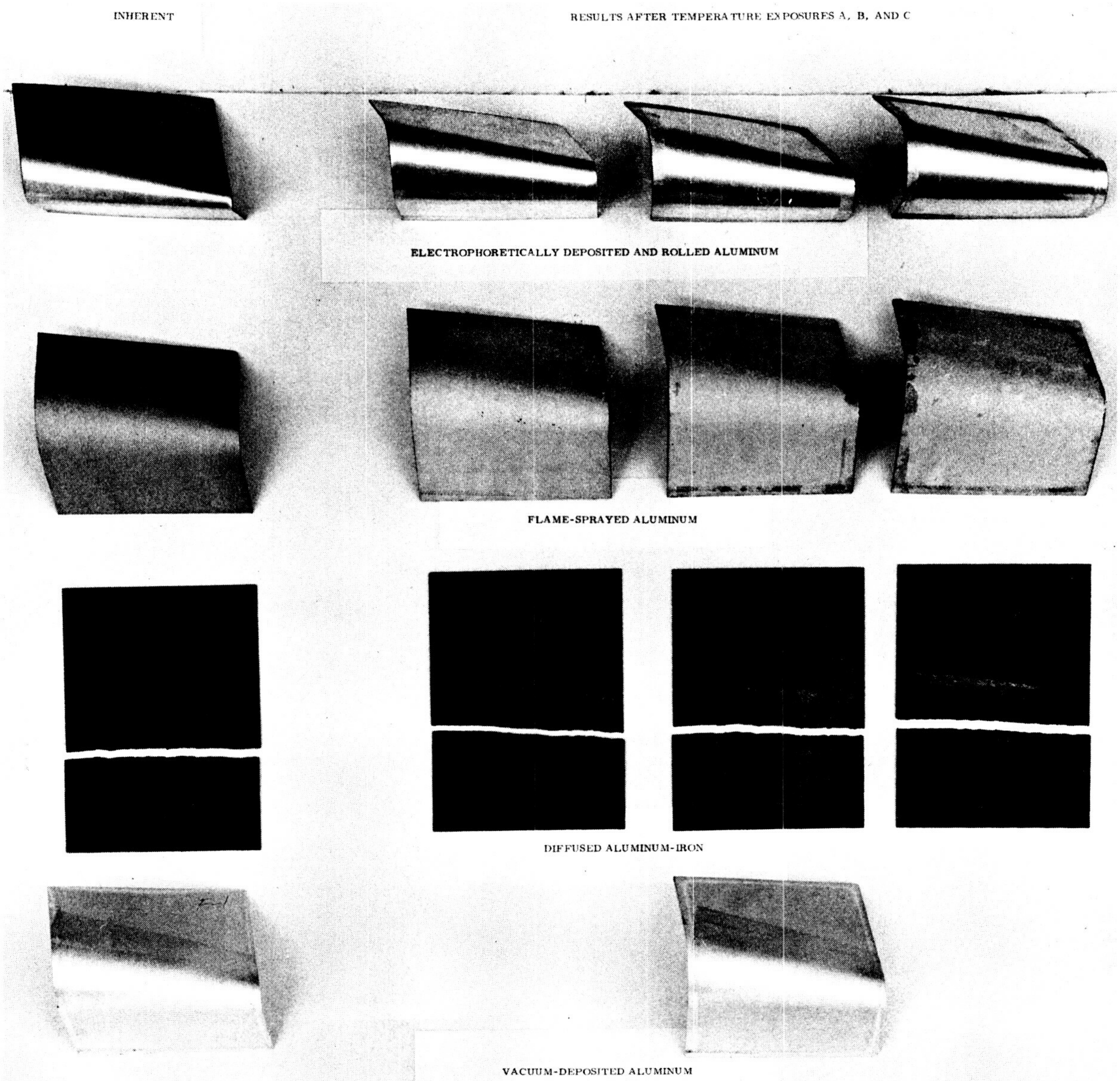
RESULTS OF SALT SPRAY EXPOSURE

Figure 13. Appearance of "DA-9" Aluminum, "Pyre-M. L." varnish, and the 7075 clad aluminum control specimen after 150 hours salt spray in the thermally damaged conditions.

The coatings are arranged in the same sequence used for Figures 2 through 7 and Figures 8 through 13. The border that appears on some of the specimens was caused by paraffin wax that was mistakenly applied to the specimens when the salt-spray specimens were prepared. The white powder used as a lubricant during bending is also visible on some of the specimens and should be ignored.

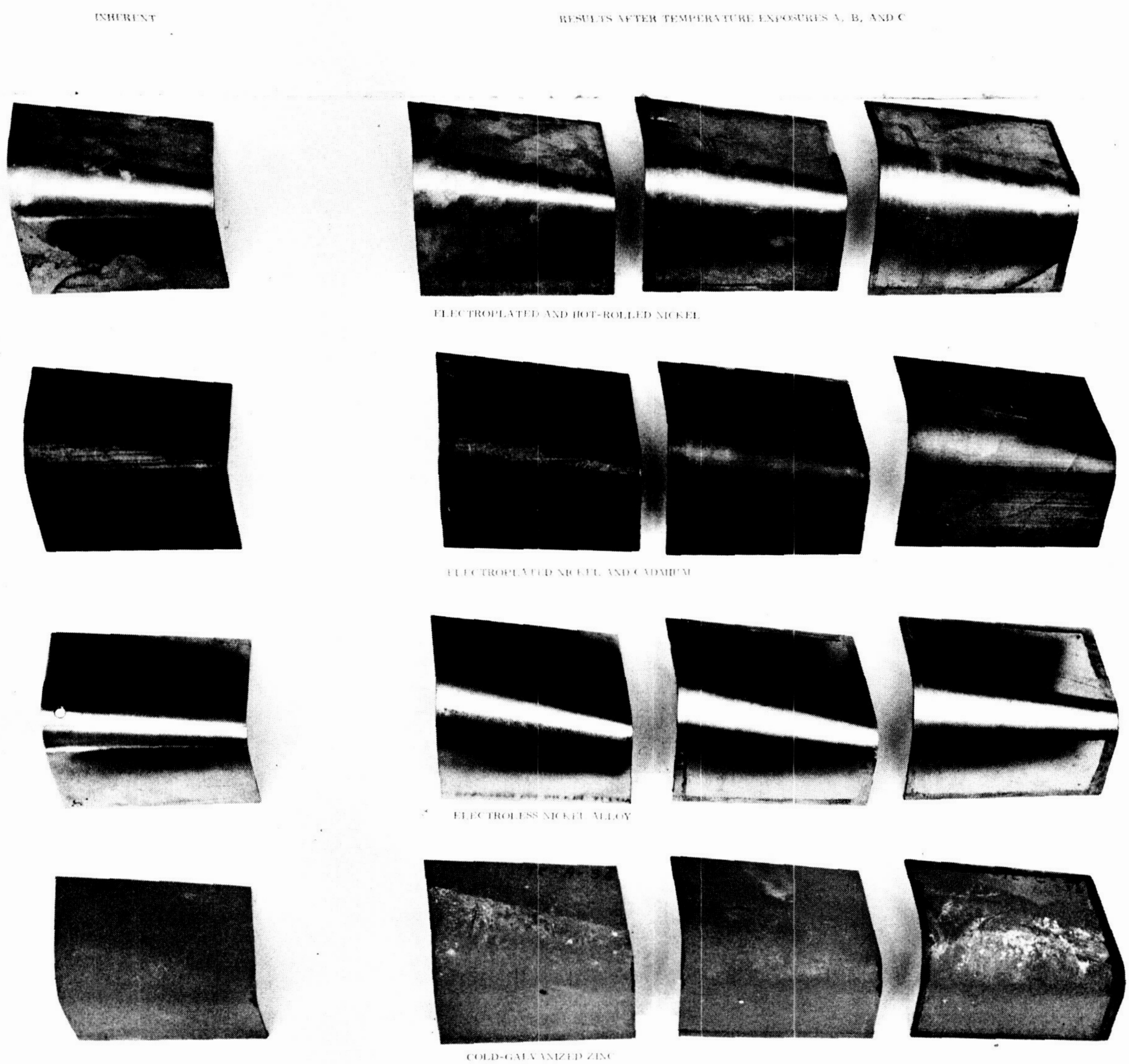
In Figure 14, all of the specimens coated with Electrophoretically Deposited and Rolled Aluminum, Flame-Sprayed Aluminum, and Vacuum-Deposited Aluminum were successfully bent without failures occurring in the coatings. The apparently sharper bends in the specimens of Electrophoretically Deposited and Rolled Aluminum are the result of the small amount of springback produced by the mild steel substrate on which this coating was deposited. The Diffused Aluminum-Iron coating caused all of its specimens to fracture at the start of bending. The brittleness of these specimens cannot be attributed to the maraging heat treatment performed at Southern Research Institute after the coating was applied because uncoated specimens subjected to the same heat treatment were not embrittled. The bend specimen used to check the maraging heat treatment is shown in Figure 19. The unbent areas on the specimens show that the appearances of the Electrophoretically Deposited and Rolled Aluminum and the Flame-Sprayed Aluminum were unchanged by the heat exposures. The Diffused Aluminum-Iron and the Vacuum-Deposited Aluminum were slightly discolored by the heat exposures but the changes cannot be detected in the photographs. The Vacuum-Deposited Aluminum was subjected only to the Series B exposure because of a shortage of specimens.

In Figure 15, the Electroplated and Hot-Rolled Nickel and the Electroplated Nickel and Cadmium coatings were bent without failure, both before and after the heat exposures. Both coatings were discolored prior to heating but the heat exposures tended to increase the discolorations. The inherent-flexibility specimens from Electroless Nickel Alloy and Cold-Galvanized Zinc cracked in a network of extremely fine cracks across the full width of the bent surface. These cracks are not visible in the photograph. After exposure to each of the temperature cycles cracks could be detected only at the edges of the specimens. Therefore, it would appear that the heat exposures were beneficial to the flexibility of these two coatings. The pattern of corrosion in the corresponding specimens subjected to salt spray (Figure 9) indicate that cracks are probably present in the Electroless Nickel Alloy, even though they are not visible. Except for slight surface stains, the color of these two coatings was unchanged by the heat exposures.



RESULTS OF FLEXIBILITY EVALUATION

Figure 14. Appearance of electrophoretically deposited and rolled aluminum, flame-sprayed aluminum, diffused aluminum-iron, and vacuum-deposited aluminum after flexibility evaluations.



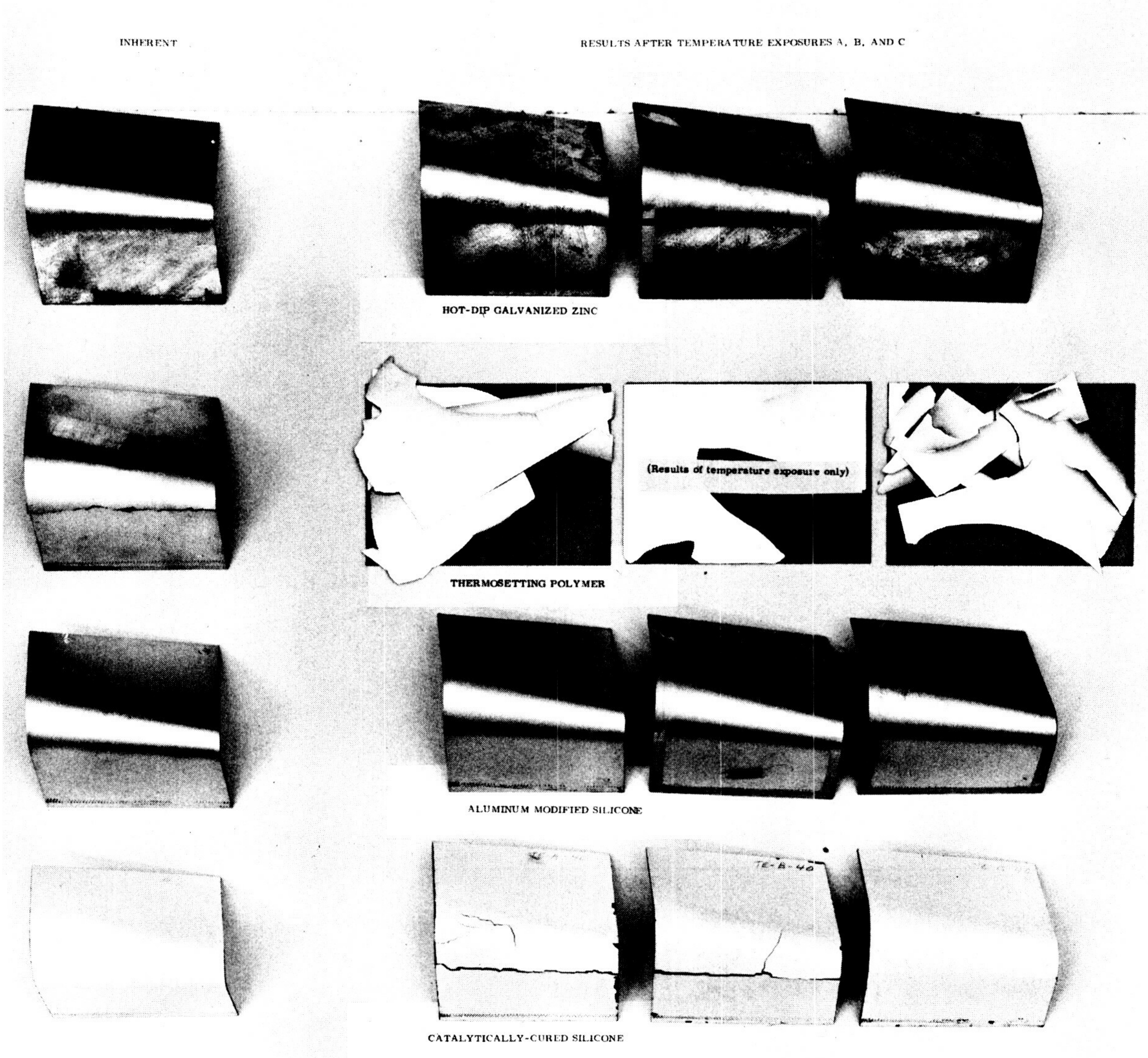
RESULTS OF FLEXIBILITY EVALUATION

Figure 15. Appearance of electroplated and hot-rolled nickel, electroplated nickel and cadmium, electroless nickel alloy, and cold-galvanized zinc after flexibility evaluations.

In Figure 16, the Hot-Dip Galvanized Zinc bent without cracking in the as-received condition and after exposure to Series A cycles. The specimen exposed to Series B cracked between the 1/2-in. -diameter edge and the 5/8-in. -diameter position shown by the pencil mark in the photograph. The specimen exposed to Series C developed fine cracks (not visible in the photograph) completely across the width of the specimen. The heat exposures also caused some dulling discolorations on this coating. The Thermosetting Polymer had poor inherent flexibility as shown by the crack that extended completely across the width of the specimen. The specimens subjected to heat exposures were not bent because the coating cracked and separated from the substrate during the heat exposures. The Aluminum-Modified Silicone was crack-free in all specimens and its appearance was essentially unchanged by the heat exposures. The stains visible in the photograph were caused by paraffin wax and externally caused chafe marks. The Catalytically Cured Silicone was free of cracks after being bent in the as-received condition but cracked completely across the specimens after exposure to Series A and Series B heat cycling. The specimen subjected to Series C developed a mosaic pattern of cracks during that exposure. The relief afforded by the cracks apparently prevented the coating from further cracking during the bend.

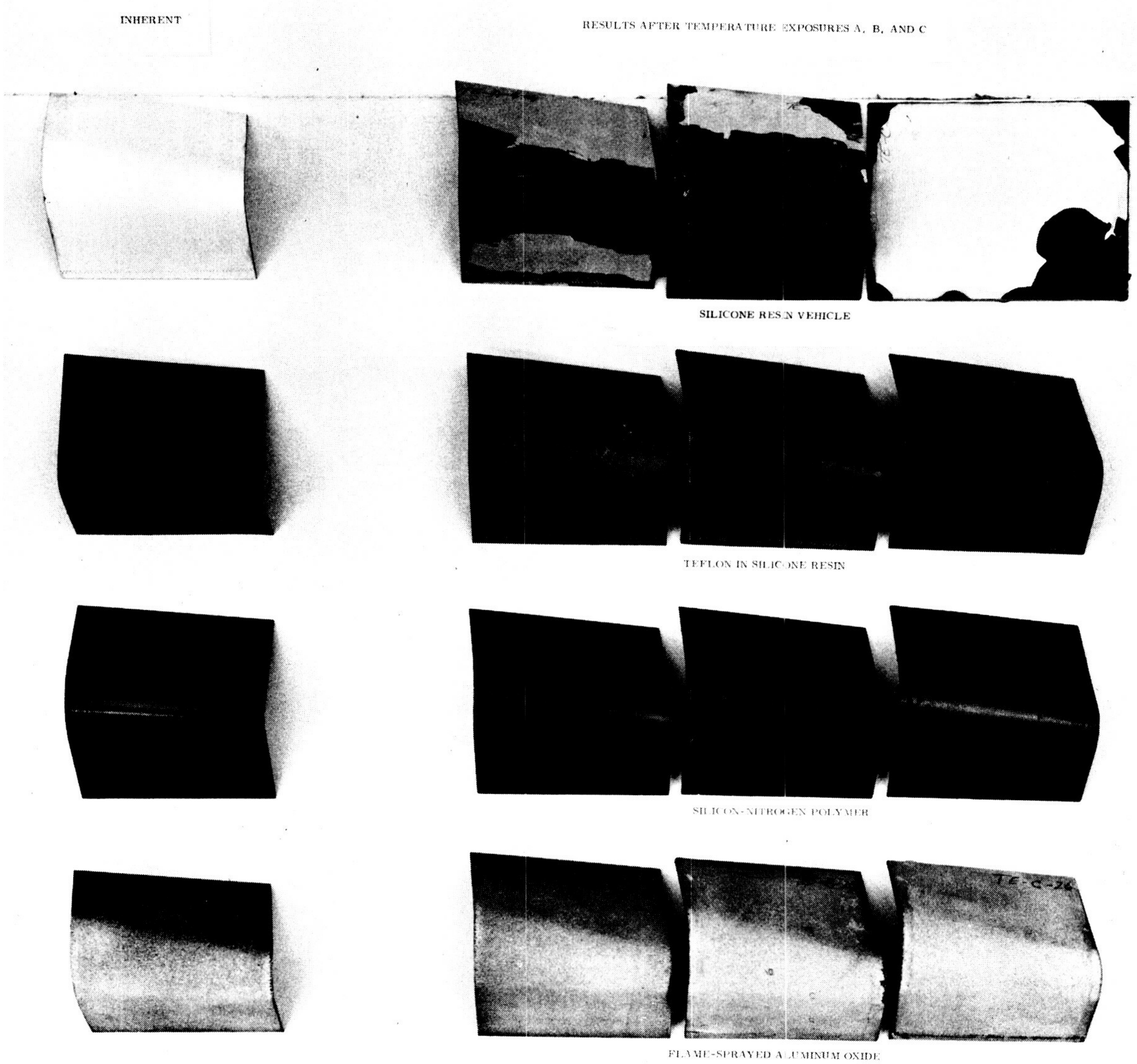
In Figure 17, the as-received specimen of Silicone Resin Vehicle did not fail in bending but the Series A and Series B exposures caused it to crack and spall from the substrate during the subsequent bending. The specimen subjected to Series C was not bent because the coating had already partially spalled from the substrate during the heat cycling. The Teflon in Silicone Resin and the Silicon-Nitrogen Polymer survived the bending without failures in all four conditions. Both coatings discolored slightly under the influence of the heating cycles. The Flame-Sprayed Aluminum Oxide developed fine cracks completely across the inherent-property specimen. After exposure to the three series of heating cycles, however, the bending produced no visible cracks even though the bent surface had a frostier appearance. These results tend to confirm the beneficial effects imparted to this coating by the heat exposures, as noted earlier in the salt-spray results (Figures 5 and 11).

In Figure 18, the Fused-Minerals coating exhibited satisfactory flexibility in all specimens except the one exposed to Series B heating cycles, which cracked in both coating and substrate before the specimen had bent 90° . Zinc Silicate had poor flexibility characteristics in all conditions. The inherent-property specimen developed small cracks extending from the 1/2-in. -diameter edge to the 7/8-in. -diameter position. The Series A specimen was similarly cracked to the 9/16-in. -diameter position, and the Series C specimen had visible cracks at the 3/4-in. -diameter position. None of the cracks are visible in the photograph. The Series B specimen



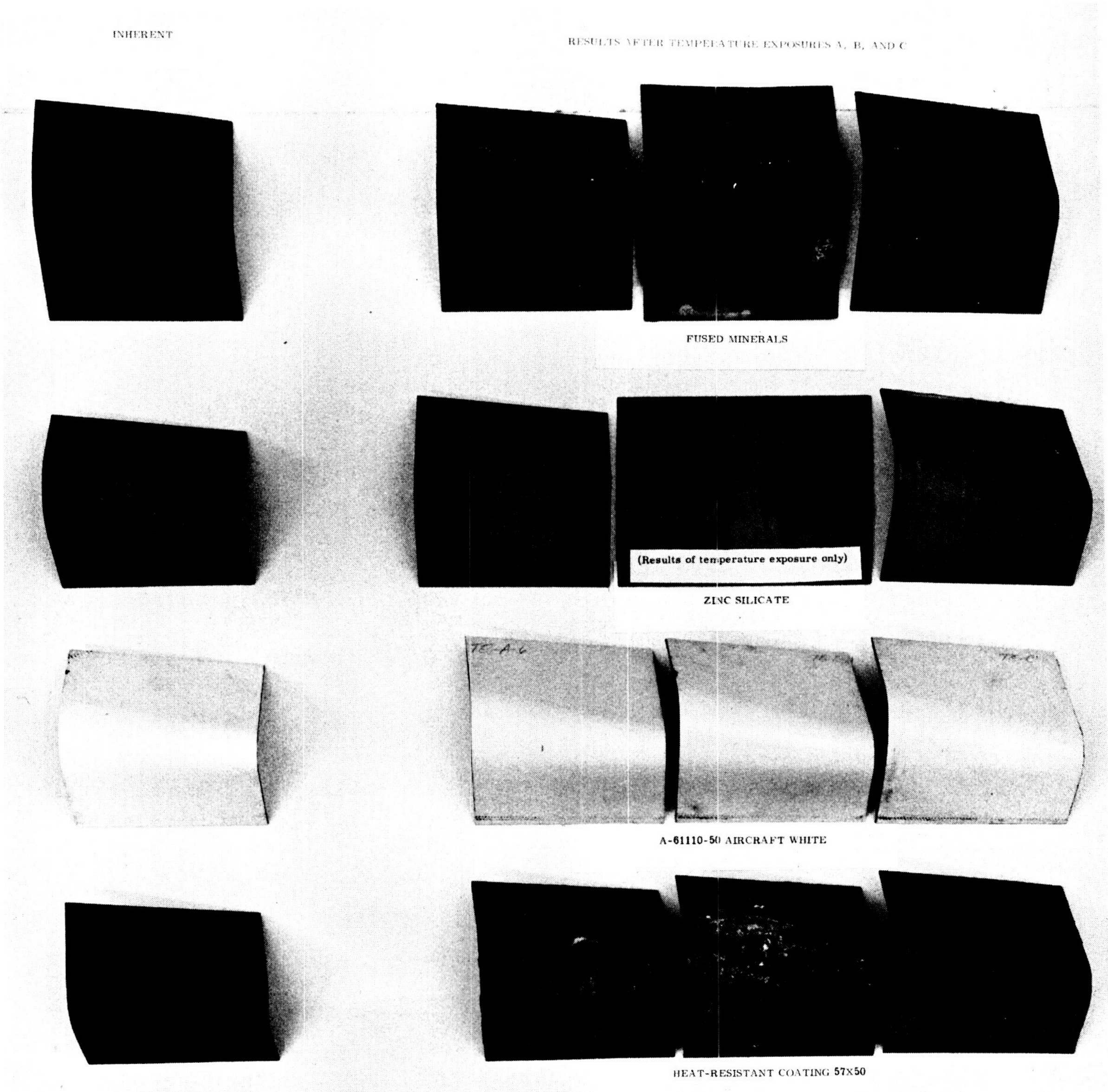
RESULTS OF FLEXIBILITY EVALUATION

Figure 16. Appearance of hot-dip galvanized zinc, thermosetting polymer, aluminum-modified silicone, and catalytically cured silicone after flexibility evaluations.



RESULTS OF FLEXIBILITY EVALUATION

Figure 17. Appearance of silicone resin vehicle, Teflon in silicone resin, silicon-nitrogen polymer, and flame-sprayed aluminum oxide after flexibility evaluations.



RESULTS OF FLEXIBILITY EVALUATION

Figure 18. Appearance of fused minerals, zinc silicate, A-61110-50 aircraft white, and heat-resistant coating 57X50 after flexibility evaluations.

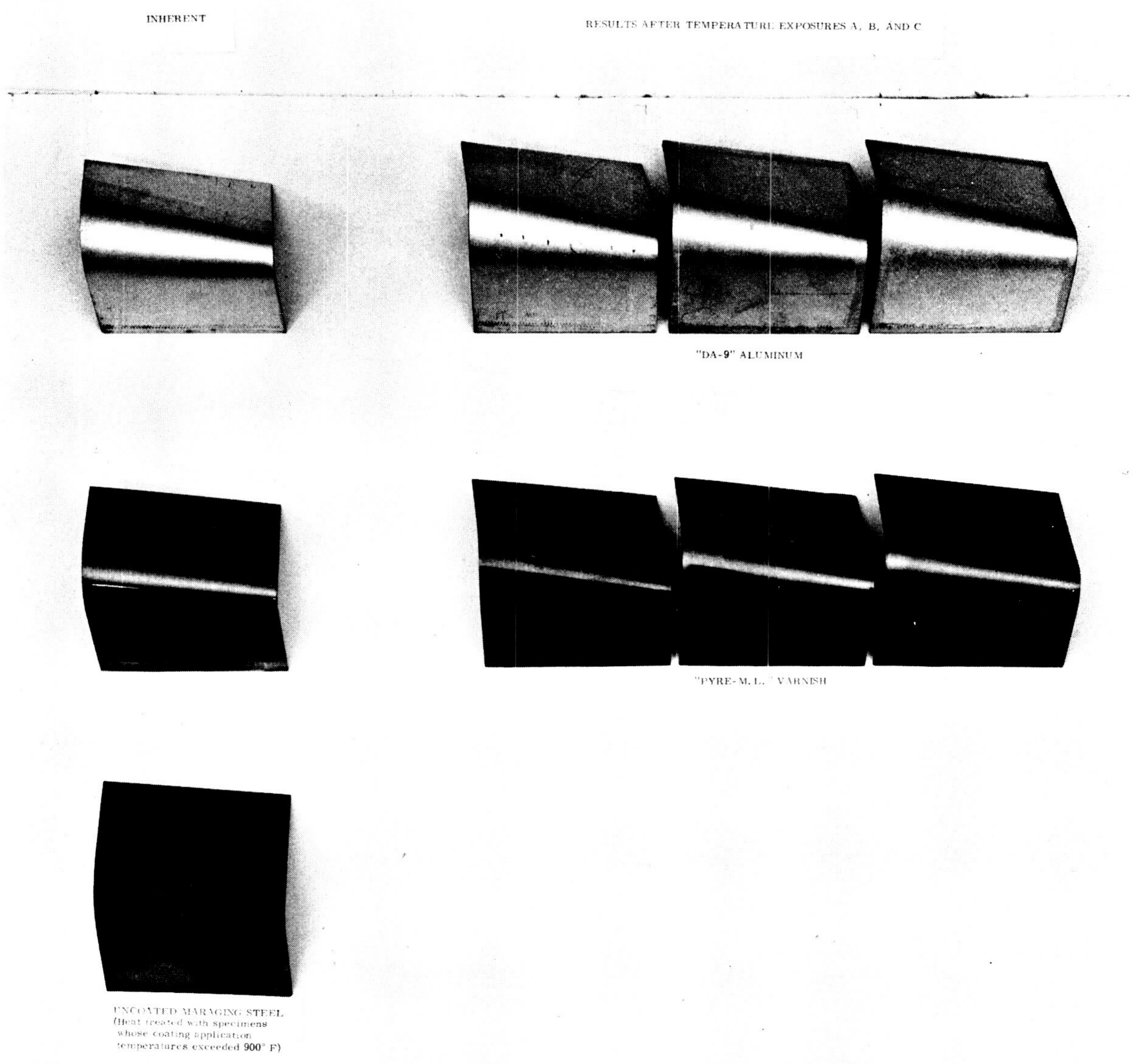
was not subjected to bending because the coating spalled off of the substrate during the heat-cycle exposure. The A-61110-50 coating had adequate flexibility in the as-received condition but developed cracks in each of the heat-exposed specimens. In the Series A specimen cracks extended from the 1/2-in.-diameter edge to the 3/4-in.-diameter position shown in the photograph by the short ink mark. The specimens from Series B and Series C heat exposures developed cracks completely across the width of the specimen. None of these cracks are visible in the photograph. Mosaic-patterned cracks that were produced by the Series C exposures are visible, however. The photograph also shows that this coating darkened considerably in the heat exposures. The inherent-property specimens of Heat-Resistant Coating 57X50 developed cracks from the 1/2-in.-diameter edge to the 9/16-in.-diameter position. The Series A and Series B specimens developed cracks completely across the width of the specimen but no cracks developed in the Series C specimen. None of the cracks are visible in the photograph. The color change caused in this coating by the heat exposures is discernable in the photograph.

The remaining coatings are shown in Figure 19. "DA-9" Aluminum had satisfactory flexibility in both the as-received and heat-exposed conditions. The heat exposures caused slight discoloration and staining of the coating. "Pyre-M. L." Varnish also had satisfactory flexibility under all conditions but the Series B exposure caused a portion of the coating to peel from the substrate. The uncoated specimen of maraging steel heat-treated by Southern Research Institute was bent for comparison with the bending characteristics of the samples coated with the Diffused Aluminum-Iron and the Fused-Minerals coatings. Post-coating heat treatment was necessary for these two coatings because the application temperatures exceeded 900° F, the aging temperature that imparts the desired strength properties to the maraging-steel substrate. The uncoated specimen bent satisfactorily, indicating that the heat treatment produced no adverse effects on the ductility of the substrate.

All of the experimental results are tabulated in Appendix D.

Evaluation System for Experimental Results

The detailed results were subjected to a numerical rating system in order to obtain a single score that would serve to rate the coatings and the control alloy according to their suitability for SST service. The rating system used for the experimental results is shown in Table III.



RESULTS OF FLEXIBILITY EVALUATION

Figure 19. Appearance of "DA-9" aluminum, "Pyre-M. L." varnish and uncoated maraging steel after flexibility evaluations.

Table III

Numerical Rating Systems for Experimental Results

Corrosion Protection[1]

Result	No.
Unchanged	10
Light discoloration, substrate uncorroded	9
0 to 10% discoloration, substrate uncorroded	8
10 to 50% discoloration and/or light deposits and/or light point corrosion, substrate uncorroded	7
50 to 100% discoloration and/or moderate deposits and/or moderate point corrosion, substrate uncorroded	6
Heavy deposits and/or substrate uncorroded and/or heavy point corrosion	5
Substrate uncorroded except at locations of mechanical damage	4
0 to 10% substrate corrosion and/or flow from impact location	3
10 to 50% substrate corrosion and/or flow from hardness indentations	2
50 to 75% substrate corrosion	1
75 to 100% substrate corrosion	0

Resistance to Temperature Exposures[2]

Result	No.
Unchanged	10
Slight surface stains, no cracking	9
0 to 10% discoloration, no cracking	8
10 to 50% discoloration, no cracking	7
50 to 100% discoloration, no cracking	6
Short[4] cracks or blisters	5
Mosaic cracking, but no separation from substrate	4
0 to 10% cracking and separation from substrate	3
10 to 50% cracking and separation from substrate	2
50 to 75% cracking and separation from substrate	1
75 to 100% cracking and separation from substrate	0

Flexibility[3]

Result	No.
No failures, bend radius 0.25 in. or less	6
Edge failures only	5
Safe bend radius between 0.25 in. to 0.313 in.	4
Safe bend radius between 0.313 in. to 0.375 in.	3
Safe bend radius between 0.375 in. to 0.438 in.	2
Safe bend radius between 0.438 in. to 0.50 in.	1
Safe bend radius greater than 0.50 in.	0

[1] These descriptions apply to corrosion protection under each of the following conditions: inherent; after penetration damage; after impact damage; and after thermal damage.

[2] These descriptions apply to resistance to temperature exposures under each of the following conditions: thermal damage (Series A); thermal shock (Series B); and low temperature (Series C).

[3] These descriptions apply to flexibility under each of the following conditions: inherent and after thermal damage.

[4] 1/8-in. long or less.

Regardless of the properties shown by a promising coating, other factors such as ease of initial application, ease of repair and maintenance, effect of application temperatures on substrate heat treatment, cost of application, and estimated service life have considerable bearing on the practicality of the coating. Therefore, the experimental results were supplemented with estimated values for these practicality aspects. The numerical rating systems devised for the practicality aspects are shown in Table IV. Since these ratings could not be based on experimental results, the rating systems were necessarily based on the authors' opinions regarding the relative importance of the various factors. During the development of this system, classifications within each of the practicality aspects were listed, and each classification was assigned a numerical value that decreased in magnitude as the classification was deemed less practical for the intended application. For example, application temperatures, difficulty of application, number of applications, and application method were considered in the design of a rating system for the aspect of ease of initial application. It was judged that painting techniques (including spraying, brushing, or dipping) could be used more readily than others, so these techniques were assigned a value of 10. On further consideration of the techniques, it was decided to assign a range of values (4 to 10) to them in order to more accurately rate the difficult painting techniques (such as those that required more than one coat or curing at elevated temperatures) in comparison with other techniques such as flame spraying. The most difficult technique was judged to be vacuum deposition and a range of values from 0 to 2 was assigned to it. In between the extremes of spray-painting techniques and vacuum deposition, as the other techniques were judged progressively more difficult, the numbers assigned to them were progressively lower. Other practicality aspects were rated similarly.

The numerical ratings assigned to each of the coatings are listed in Table V. This table lists each of the 22 experimentally evaluated coatings and shows the coating number, the type of coating, the ratings obtained from the experimental results, the total score obtained on the basis of experimental results alone, the ratings obtained from the practicality aspects, the total score, the standing within each coating category (metallic, organic, etc.), and the relative rank of the coating with respect to each of the others.

The total scores shown in Table V have been plotted as bar charts in Figures 20 and 21. Figure 20 is a plot of the scores obtained from the experimental results alone, whereas Figure 21 is a plot of scores that include both the experimental results and the ratings of practicality aspects. In these plots, each coating is represented by a bar that extends to a length determined by its score. The bars are arranged from left to right in descending order

Table IV

Numerical Rating Systems for Practicality Aspects of Coatings

Ease of Initial Application
(Application Temperatures & Difficulty of Application)

Classification	No.
Spray painting techniques (brushing or dipping)	4-10
Hot dipping	8-9
Flame spray techniques	7-8
Electroplated on sheet (and electroless)	5-6
Electroplated on sheet and diffused	4-5
Electroplated (or electrophoretic) and rolled	2-4
Diffusion coatings	0-3
Vacuum deposited	0-2

Ease of Repair and Maintenance

Classification	No.
Spray painting techniques (brushing or dipping)	8-10
Electroplating (simple and electroless)	6-8
Flame spraying	4-6
Hot dipping	2-4
All others	0-2

Effect of Application Temperature on Substrate
Heat Treatments

Classification	No.
No elevated temperatures required for coating application	6
Elevated temperatures required for coating application, but substrate heat treatment not affected	4
Elevated temperatures required, substrate heat treatment affected, but reheat treatment practical	2
Elevated temperatures required, substrate heat treatment affected, but reheat treatment not practical	0

Quantity Cost per Sq. Ft.
of Surface Covered
(Surface Preparation and Application)

Dollar Classification	No.
0 to 0.10	6
0.10 to 0.50	5
0.50 to 1.00	4
1.00 to 10.00	3
10.00 to 25.00	2
25.00 to 50.00	1
Over 50.00	0

Life Expectancy Under
Normal Weathering

Classification	No.
> 10 years	6
5 to 10 years	4
2 to 5 years	2
< 2 years	0

Availability

Classification	No.
Production item	6
Development item	3
Applied research item	0

Table V

Numerical Ratings[1] of Coatings for SST Aircraft Application

Number	Type of Coating	Ratings of Experimental Results[2]: Corrosion Protection: Inherent	Corrosion Protection: Penetration Damage	Corrosion Protection: Impact Damage	Resistance to Thermal Damage: Evaluation Method[4]	Resistance to Thermal Damage: Series A	Resistance to Thermal Damage: Series B	Resistance to Thermal Damage: Series C	Inherent Flexibility	Experimental Score	Ratings of Practicality Aspects: Ease of Initial Application	Ease of Repair and Maintenance	Effect of Application Temperature	Application Cost	Life Expectancy, Normal Weathering	Present Availability	Total Score[3]	Category Standing	Relative Rank
	METALLIC																		
	Aluminum																		
1	Electrophoretically Deposited & Rolled Aluminum	6	6	6	V	10	10	9	6	45	2	1	2	5	6	3	64	5	9
					SF	6	6	6											
					F	6	6	6											
					AVG.	7	7	7											
2	Flame-Sprayed	8	8	8	V	10	10	10	6	51	8	5	4	6	4	6	84[6]	1	1
					SF	6	6	6											
					F	6	6	6											
					AVG.	7	7	7											
3	Vacuum-Deposited	1	1	0	V	6[4]	6	6	6	23	0	0	6	0	4	0	33	7	17
					SF	2	2	2											
					F	6	6	6											
					AVG.	5	5	5											
	Aluminum Alloy																		
4	Diffused Al-Fe	0	0	0	V	8	8	8	0	9	1	0	0	2	0	0	12	8	18
					SF	0	0	0											
					F	0	0	0											
					AVG.	3	3	3											
	Nickel																		
7	Electroplated & Hot-Rolled	6	6	6	V	9	6	7	6	43	3	0	6	5	4	3	64	5	9
					SF	6	6	6											
					F	6	6	6											
					AVG.	7	6	6											
8	Electroplated Ni & Cd	6	6	6	V	10	10	7	6	44	6	6	4	2	4	6	72	3	5
					SF	6	6	6											
					F	6	6	6											
					AVG.	7	7	6											
	Nickel Alloy																		
9	Electroless	2	2	2	V	9	9	9	0	21	6	6	6	5	2	6	52	6	13
					SF	1	1	1											
					F	5	5	5											
					AVG.	5	5	5											
	Zinc																		
11	Cold Galvanized	6	6	6	V	9	7	10	0	37	9	9	6	5	2	6	74	2	4
					SF	5	5	5											
					F	5	5	5											
					AVG.	6	6	7											
12	Hot-Dip Galvanized	5	5	5	V	8	6	7	5	35	9	3	4	6	4	6	67	4	6
					SF	5	5	5											
					F	6	4	0											
					AVG.	6	5	4											
	ORGANIC																		
	Polymer																		
16	Thermosetting	10	4	4	V	0	0	0	0	18	8	8	6	3	0	6	49	5	14
					SF	0	0	0											
					F	0	0	0											
					AVG.	0	0	0											
	Silicone																		
17	Aluminum-Modified	7	4	4	V	10	9	10	6	43	8	8	6	6	2	3	76	2	3
					SF	7	7	7											
					F	5	6	8											
					AVG.	7	7	8											

Table V (continued)

Numerical Ratings[1] of Coatings for SST Aircraft Application

Number	Type of Coating	Ratings of Experimental Results[2]									Ratings of Practicality Aspects								
		Corrosion Protection			Resistance to Thermal Damage														
		Inherent	Penetration Damage	Impact Damage	Evaluation Method[4]	Series A	Series B	Series C	Inherent Flexibility	Experimental Score	Ease of Initial Application	Ease of Repair and Maintenance	Effect of Application Temperature	Application Cost	Life Expectancy, Normal Weathering	Present Availability	Total Score[3]	Category Standing	Relative Rank
	ORGANIC (continued)																		
	Silicone (continued)																		
18	Catalytically Cured	7	4	4	V	10	10	2	6	34	10	10	6	5	0	0	65	3	8
					SF	7	7	0											
					F	0	0	0											
					AVG.	6	6	1											
19	Silicone Resin Vehicle	7	4	4	V	6	1	1	6	23	9	9	6	5	0	6	58	4	12
					SF	1	0	0											
					F	0	0	0											
					AVG.	2	0	0											
20	Teflon in Silicone Resin	10	4	4	V	10	8	6	6	45	8	8	6	5	2	6	80[5]	1	2
					SF	9	7	6											
					F	6	6	6											
					AVG.	8	7	6											
	SEMI-ORGANIC																		
	Polymer																		
21	Silicon-Nitrogen Chains	3	2	2	V	7	7	8	6	28	4	2	4	6	2	0	46	1	15
					SF	2	1	2											
					F	6	6	6											
					AVG.	5	5	5											
	INORGANIC																		
	Aluminum Oxide																		
24	Flame-Sprayed	5	4	6	V	10	8	10	0	36	7	4	4	1	4	6	62	2	11
					SF	3	7	7											
					F	5	5	6											
					AVG.	6	7	8											
25	Fused Minerals	2	2	3	V	7	6	6	5	24	4	0	0	5	2	6	41	3	16
					SF	3	3	2											
					F	5	0	5											
					AVG.	5	3	4											
27	Zinc Silicate	7	7	7	V	10	2	10	2	38	8	8	6	6	2	6	74	1	4
					SF	6	5	6											
					F	4	0	3											
					AVG.	7	2	6											
	OTHER																		
28	A-61110-50 (Aircraft White)	7	3	3	V	6	6	4	6	30	8	8	6	5	0	6	63	3	10
					SF	6	3	5											
					F	3	0	0											
					AVG.	5	3	3											
30	Heat-Resistant Coating 57X50	6	6	6	V	10	6	5	4	36	8	8	6	5	0	6	69	1	5
					SF	5	5	5											
					F	0	0	6											
					AVG.	5	4	5											
32	"DA-9" Aluminum	9	2	3	V	6	6	6	6	32	8	8	6	6	0	6	66	2	7
					SF	0	0	1											
					F	6	6	6											
					AVG.	4	4	4											
33	"Pyre-M. L." Varnish	7	4	4	V	6	2	6	6	36	8	8	6	5	0	6	69	1	5
					SF	9	0	7											
					F	6	5	6											
					AVG.	7	2	6											
	CONTROL																		
X	Alclad 7075 Aluminum	6	6	6	V	9	9	10	6	45	10	1	6	5	6	6	79	–	–
					SF	6	6	6											
					F	6	6	6											
					AVG.	7	7	7											

[1] Based on the systems listed in Tables III and IV.
[2] All ratings of experimental results were made at the same time so that progressive corrosion that might occur while the specimens were in storage would not occur.
[3] A perfect score equals 107.
[4] V designates visual examination after the thermal exposures; SF designates exposure to salt spray after the thermal exposures; F designates flexibility evaluation after the thermal exposures; Underline designates our estimate because specimens were not furnished for experiment.
[5] These coatings achieved ratings higher than the rating of the control material, Alclad 7075 Aluminum, which achieved a rating of 79.

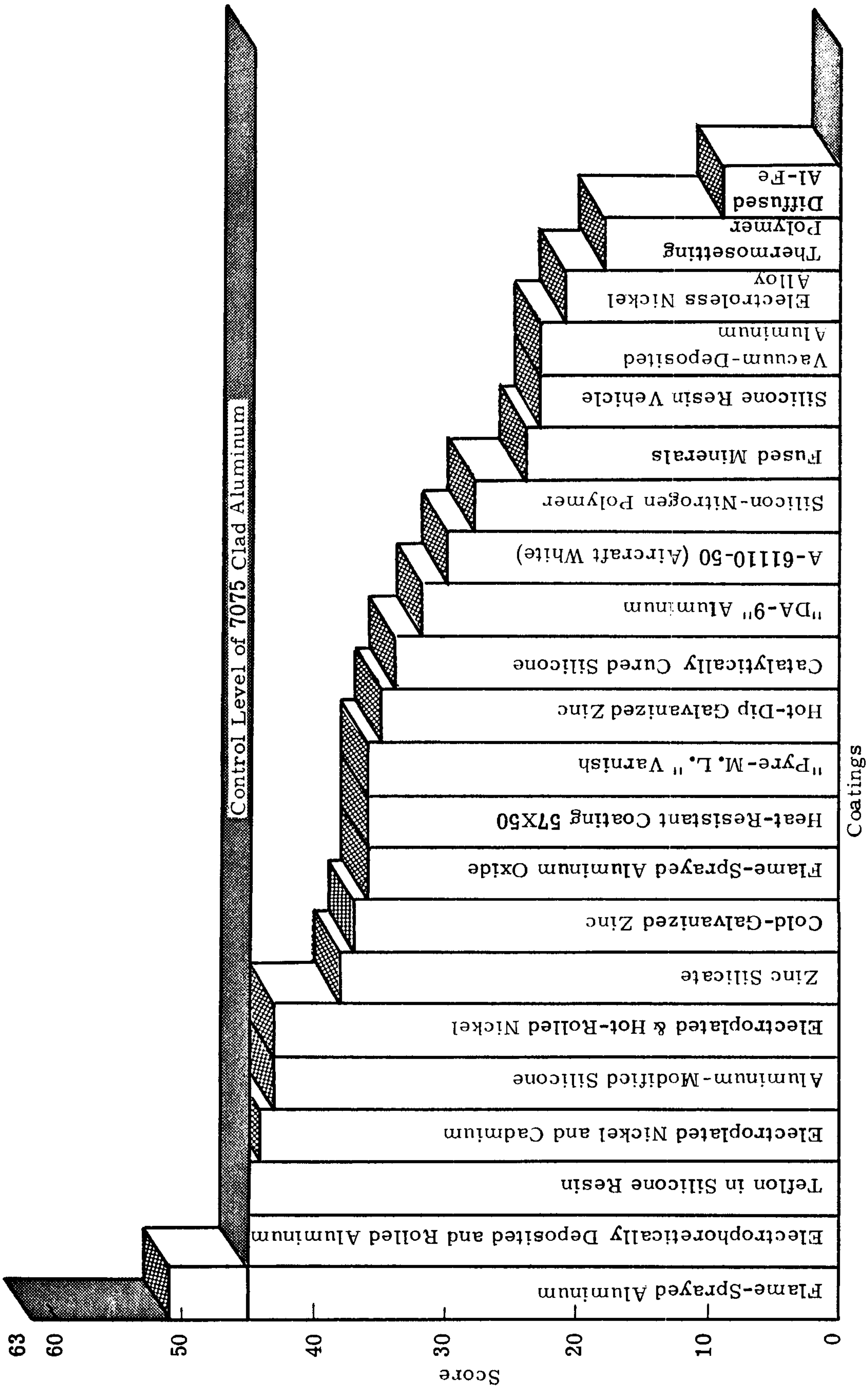


Figure 20. Scores Obtained From Experimental Results Alone.

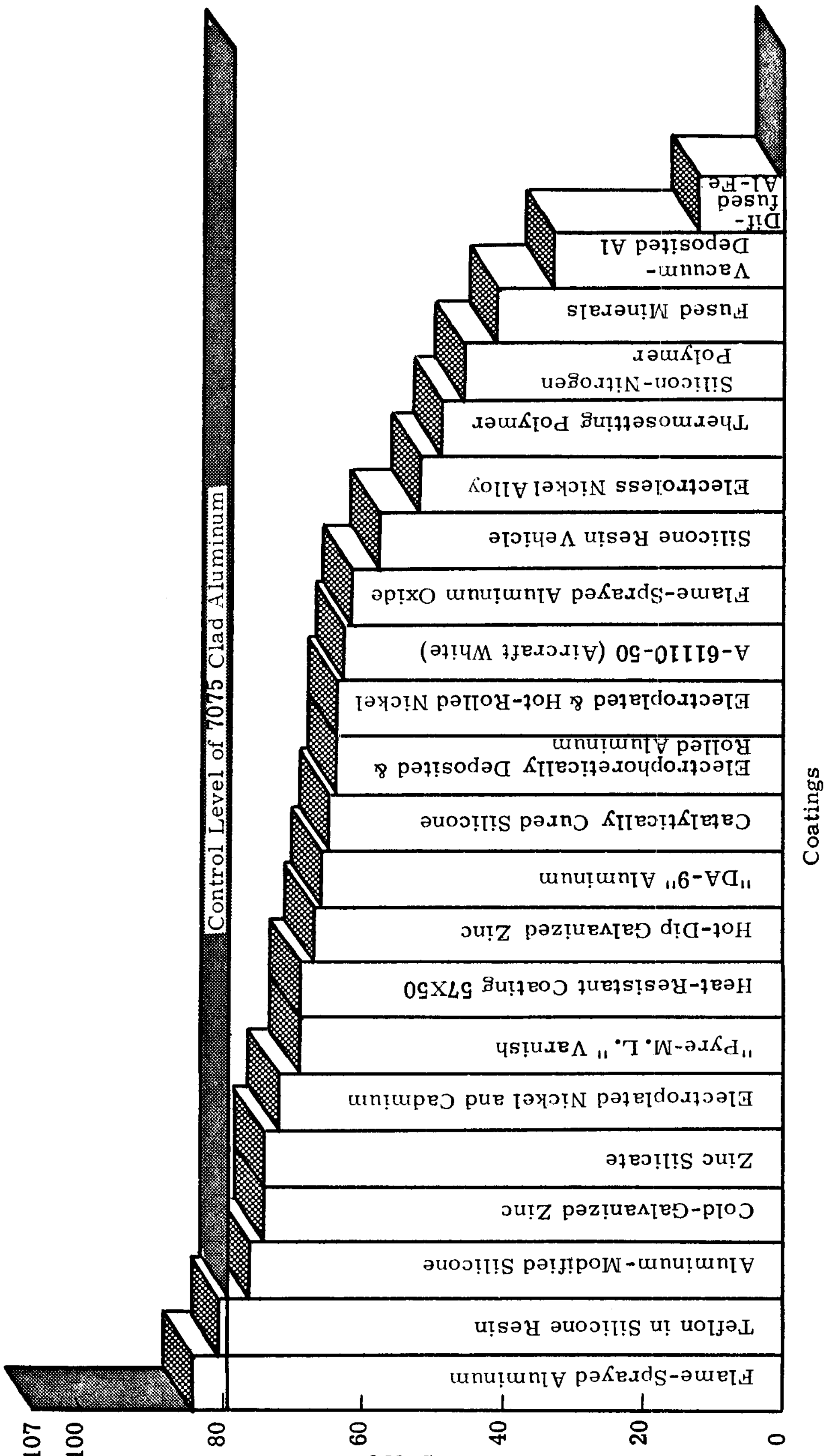


Figure 21. Total Scores Obtained from Experimental Results and Practicality Aspects.

of the scores, and the score attained by the control material is shown by a horizontal plane located at the proper level.

In both figures the coatings tend to cluster approximately into three groups; one group with a score above or slightly below the control level, another group at a slightly lower level, and a final group ranging from a moderately low to very low level. Comparison of the two figures shows a considerable shift of position of the coatings in the two high-level groups, depending upon whether the practicality aspects are included in the score (Figure 21). In the following discussion the allocation of coatings to the classifications of "promising," "conditionally promising," and "unpromising" were made on the basis of the experimental results in Figure 20. However, since the practicality aspects amount to approximately 40% of the total score, and since they account for the reduction of several coatings from the promising to the conditionally promising level in Figure 21, the final suitability of the promising coatings will depend in large part upon whether the practicality aspects prove to be of great importance in the design, construction, and maintenance of the SST.

Promising Coatings

Figure 20 shows the most promising coatings to be:

Flame-Sprayed Aluminum
Electrophoretically Deposited and Rolled Aluminum
Teflon in Silicone Resin
Electroplated Nickel and Cadmium
Aluminum-Modified Silicone
Electroplated & Hot-Rolled Nickel

Flame-Sprayed Aluminum achieved excellent ratings that exceeded the control material in practicality results as well as in the experimental results. The main factor contributing to its superiority over other aluminum surfaces in the experimental results was that it formed less aluminum-corrosion products. In the practicality results it excelled because of its relative ease of application and repair compared to the other metallic aluminum coating (Electrophoretically Deposited and Rolled). The major defect of the coating is its dull gray appearance, a characteristic that was not counted in the evaluation scores.

Electrophoretically Deposited and Rolled Aluminum is an excellent coating from the standpoint of the experimental results. Its original appearance has the bright and shiny surface that is characteristic of rolled aluminum alloys. Its behavior in the experiments was similar to the behavior of the control alloy and it achieved the same experimental score. At present, however, its practicality score is quite low because it is a developmental coating that has only been applied to mild steel. Whether it can be successfully applied to other substrates is not known, although the developer (BISRA) is highly optimistic that it can be. It is a coating that must be applied by sheet-mill operations and cannot be repaired in the field except by replacement of complete parts or panels. It is not likely to need spot repair, however. Because it can only be supplied in sheet form, consideration must be given to the effects of the exposed edges that will exist wherever the sheet is cut to form parts. The future availability of this coating is also uncertain because it has only been produced in pilot-plant lots. Production facilities (for mild steel substrate) are being planned but it is not yet known how successful the scaling up from the pilot plant will be. Despite these shortcomings of practicality, the excellent performance characteristics of Electrophoretically Deposited and Rolled Aluminum make it a strong candidate coating until it is definitely determined that one or more of the practicality aspects precludes its use.

Teflon in Silicone Resin attained high scores in both experimental and practicality results. It is a relatively soft coating, however, and may require frequent repair or replacement. Fortunately, its application procedure is simple except for the 450° F baking temperature needed to cure it. The coating is dark in color but has a smooth surface finish. Although its color and softness may preclude its use as a surface coating, Teflon in Silicone Resin should be an excellent material for sealing joints and for protection of edges of sheet material on which non-repairable coatings provide the surface protection.

Although Electroplated Nickel and Cadmium performed well in the experimental determinations, it has several shortcomings in the practicality aspects. Its application procedure involves two electroplating operations and a diffusion treatment that (at 620° F) is slightly lower than the maximum expected service temperature for SST aircraft skins. The possibly deleterious effects of continued diffusion, and the effects of diffusion layers on fatigue life, are not known. The coating after the diffusion treatment is dark and non-uniform in color, a characteristic that will require some type of top coating for the sake of satisfactory appearance.

Aluminum-Modified Silicone is the only paint-type coating (among the promising coatings) that has the bright and shiny appearance of metallic aluminum. Its high rating in both the practicality and experimental evaluations, combined with its color and surface appearance, make it a most attractive candidate coating, either for use alone or as an edge coating for sheet covered with metallic coatings. It is subject to deterioration by mechanical damage, but it is a much harder coating than the Teflon in

Silicone Resin, and its application procedure is such that the repair of mechanical damage should not prove to be excessively troublesome.

Electroplated and Hot-Rolled Nickel is another coating that can only be obtained in the precoated form; consequently, it attained a relatively low practicality rating because it cannot be easily repaired in the field. It is not likely to need repair, however, and if precoated sheets with exposed edges are determined to be practical for the construction of the aircraft, it should be an excellent coating.

Conditionally Promising Coatings

The conditionally promising coatings are those in Figure 20 that extend down to a score of 32 (approximately 75% of the control score). They are:

Zinc Silicate
Cold-Galvanized Zinc
Flame-Sprayed Aluminum Oxide
Heat-Resistant Coating 57X50
"Pyre-M. L." Varnish
Hot-Dip Galvanized Zinc
Catalytically Cured Silicone
"DA-9" Aluminum

The zinc coatings in this group —Zinc Silicate, Cold-Galvanized Zinc, and Hot-Dip Galvanized Zinc —behaved similarly. They all provided excellent corrosion protection for the substrate but, in doing so, corroded sacrificially and produced objectionable deposits. The two paint-type coatings, Zinc Silicate and Cold-Galvanized Zinc, corroded only slightly in the as-received condition but, after exposure to heat, corroded to the same extent as the Hot-Dip Galvanized coating. Although their original appearance and their tendency to self-corrode would probably make it necessary to cover them with another coating, the galvanic protection they provide to damaged areas may prove to be of some importance. All of the zinc coatings failed to meet some of the flexibility requirements, but the two paint-type coatings can be applied after parts are formed, and the hot-dipped coating did not lose flexibility until after it was exposed to some of the heating cycles. It is quite possible that some of the pigmented paints would perform more satisfactorily over an undercoat of zinc than they did when applied to the substrate itself.

The performance of Flame-Sprayed Aluminum Oxide was somewhat erratic with respect to corrosion protection. For no apparent reason, some of the specimens were protected satisfactorily and others showed a considerable amount of point corrosion. However, considering the severity of the salt-spray exposure it is likely that this coating will provide satisfactory protection in atmospheric conditions. The flexibility of the coating was relatively poor but improved when exposed to the heating cycles. Although its performance placed this coating in the conditionally promising category, its relatively high cost and its erratic behavior make it the least practical coating in the promising and conditionally promising groups.

The remaining coatings in the conditionally promising group—Heat-Resistant Coating 57X50, "Pyre-M. L." Varnish, Catalytically Cured Silicone, and "DA-9" Aluminum—are paint formulations that performed well until exposed to some of the heating cycles. The appearance of some of the heated specimens indicated that although the coating was impervious to the corroding medium, it was not impervious to oxygen, and allowed the substrate to oxidize when heated to 650° F. The oxidation under the coatings caused them to lose adherence, change color, or provide less corrosion protection. Therefore, it these coatings were applied to substrates or undercoats that were not readily oxidized, their performance might improve considerably.

Unpromising Coatings

Because of various characteristics that were revealed by the experimental exposures, the following coatings, which appeared to be promising on the basis of the literature and industrial survey, have little promise for meeting SST service conditions.

A-61110-50 (Aircraft White)
Silicon-Nitrogen Polymer
Fused Minerals
Silicone Resin Vehicle
Vacuum-Deposited Aluminum
Electroless Nickel Alloy
Thermosetting Polymer
Diffused Aluminum-Iron

CONCLUSIONS

1. Within the scope of this preliminary screening program, 14 coatings have been shown to be promising or conditionally promising for corrosion protection of skin materials on SST aircraft.

2. The most promising coatings are:

   a. Flame-Sprayed Aluminum
   b. Electrophoretically Deposited and Rolled Aluminum
   c. Teflon in Silicone Resin
   d. Electroplated Nickel and Cadmium
   e. Aluminum-Modified Silicone
   f. Electroplated and Hot-Rolled Nickel

3. The coatings showing conditional promise are:

   a. Zinc Silicate
   b. Cold-Galvanized Zinc
   c. Flame-Sprayed Aluminum Oxide
   d. Heat-Resistant Coating 57X50
   e. "Pyre-M. L." Varnish
   f. Hot-Dip Galvanized Zinc
   g. Catalytically Cured Silicone
   h. "DA-9" Aluminum

4. The following coatings, which appeared to be promising on the basis of the literature and industrial surveys, were indicated by the experimental program to be less suitable for SST applications:

   a. A-61110-50 (Aircraft White)
   b. Silicon-Nitrogen Polymer
   c. Fused Minerals
   d. Silicone Resin Vehicle
   e. Vacuum-Deposited Aluminum
   f. Electroless Nickel Alloy
   g. Thermosetting Polymer
   h. Diffused Aluminum-Iron

5. Further evaluations of the most promising of the coatings and combinations of them will be necessary before the selection of suitable coatings can be made with a high degree of confidence. These evaluations should include the determination (under simulated SST service conditions) of the effects of the coatings on the fatigue, stress-corrosion, and static-strength properties of the proposed substrate materials.

6. The final selection of coatings will depend in part on certain design, construction, and maintenance considerations that have not yet been determined for the SST aircraft.

BIBLIOGRAPHY

1. Fabian, R. J., "New Coatings from the Plasma Arc," Materials in Design Engineering, November 1961, p 127.

2. Fabian, R. J., "Coatings for the Refractory Metals," Materials in Design Engineering, November 1961, p 129.

3. Fabian, R. J., "New Metallic Diffusion Coatings," Materials in Design Engineering, November 1961, p 133.

4. Hauser, R. L., "Ablative Coatings," Materials in Design Engineering, November 1961, p 135.

5. Anonymous, BISRA Steel Strip Developments, Aluminum Coating and Continuous Annealing," Metallurgia, April 1962, pp 171-173.

6. Decker, R. F., "The Maraging Steels," Materials in Design Engineering, 55, No. 5, May 1962.

7. Maisel, Leonard, "Metal Filming Methods Other than Electrodeposition," Metal Finishing, July 1962, pp 32-43.

8. King, P., "Diffusion Coatings," Product Engineering, 33, No. 13, 25 June 1962.

9. Spencer, L. F., "Surface Finishing Stainless Steels," Metal Finishing Guidebook Directory, 30th Edition, 1962, p 143.

10. Anonymous, "Aluminum-Coated Steel," Metal Industry, 9 March 1962.

11. Anonymous, "Versatile Satin Nickel Finish," Metal Industry, 16 March 1962.

12. Maisel, Leonard, "Finishing by Mechanical Plating Methods," Products Finishing, 26, No. 6, March 1962, p 50.

13. Crabtree, R. N., "High-Speed Roller Coating of Metal Coil Stock," Products Finishing, 26, No. 6, March 1962, p 38.

14. Fabian, R. J., "Guide to Electroplated Coatings," Materials in Design Engineering, 55, No. 2, February 1962.

15. Nessler, C. G., "Plasma Arc Coatings," Materials in Design Engineering, 55, No. 6, June 1962, p 109.

BIBLIOGRAPHY (Continued)

16. Van Laar, J. A. W., "The Durability of Paint Coatings," Corrosion Prevention and Control, 9, March 1962, pp 57-60.

17. Preuss, H. P., "Organic Finishing Developments of 1961," Metal Finishing, 60, No. 1, January 1962, p 54.

18. Belcher, K. H., "Developments in Ni-Cr and Electroless Nickel Plating," Journal of the Australian Institute of Metals, 6, No. 4, November 1961.

19. Butler, J. M., Schwendeman, J. L., and Hathaway, C. E., "High Temperature Organic and Semi-Organic Coatings," First Quarterly Progress Report to Aeronautical Systems Division, Monsanto Research Corporation, 1 May 1962 to 1 August 1962.

20. Gibeaut, W. A. and English, J. J., "Oxidation-Resistant Coatings for Refractory Metals, "Review of Recent Developments - DMIC, August 3, 1962.

21. Walton, J. D., Jr., "Present and Future Problem Areas for High Temperature Inorganic Coatings," The American Ceramic Society Bulletin, 40, No. 3, March 15, 1961.

22. Lacey, Robert E., "Silicon-Nitrogen Compounds—A New Class of Materials," Bulletin of Southern Research Institute, XV, No. 1, Summer 1962.

23. Anonymous, "Practical Lower-Cost Process Diffuses Chromium Into Steel," The Iron Age, February 11, 1960.

24. Gailer, J. W., and Vaughan, E. J., Protective Coatings for Metals, Charles Griffin & Co., Ltd., 1950.

25. Burns, R. M. and Schuh, A. E., Protective Coatings for Metals, Reinhold Publishing Corp., 1939.

26. Anonymous, "Charged Ceramics Coat Metals," The Iron Age, November 8, 1962, p 114.

27. Wiederholt, W., "Laboratory Corrosion Testing," Section XIV.6, First International Congress on Metallic Corrosion, Butterworths, 1962, pp 694-702.

BIBLIOGRAPHY (Continued)

28. Noble, H. J. and Sharp, W. H., "Steels and Protective Treatments for Use Up to 1000° F," SAE Transactions, Vol 64, 1956, pp 59-75.

29. Fabian, Robert J., "Corrosion—Special Report No. 22," Materials in Design Engineering, Vol. 57, No. 1, January 1963, pp 83-122.

30. Greenberg, D.S., "Supersonic Transport: Next Step in Civil Aviation Is a Difficult One," Science, 138, No. 35-45, 7 December 1962, p. 1083.

31. Fabian, Robert J., "What's New in Coatings and Finishes," Materials in Design Engineering, Vol. 57, No. 4, April 1963, pp 109-116.

32. Anonymous, "Heat-Proof Paints Save Molds," The Iron Age, Vol. 191, No. 9, February 28, 1963, pp 77-78.

33. Deutsh, George C., "Materials for a Supersonic Transport," Journal of Metals, Vol. 15, No. 3, March 1963, pp 185-189.

34. Jackson, J.H., "For a Supersonic Transport: I. Aluminum," Journal of Metals, Vol. 15, No. 3, March 1963, pp 190-191.

35. Erbin, E. F., "For a Supersonic Transport: II. Titanium," Journal of Metals, Vol. 15, No. 3, March 1963, pp 192-193.

36. Marshall, M.W., "For a Supersonic Transport: III. Steel," Journal of Metals, Vol. 15, No. 3, March 1963, pp 194-195.

37. Clark, C. C., "For a Supersonic Transport: IV. Superalloys," Journal of Metals, Vol. 15, No. 3, March 1963, pp 195-196.

38. Denke, Paul H., "Problems in Selecting Alloys for the Supersonic Transport," Metal Progress, Vol. 83, No. 3, March 1963, pp 71-124.

39. Brown, D. R. and Jackson, A. E., "The 'Elphal' Strip-Aluminizing Process," Preprint from Sheet Metal Industries, March 1963.

40. Stetson, A. R., "Titanium Coatings Protect Metals," Materials in Design Engineering, 57, No. 3, March 1963, pp 81-84.

BIBLIOGRAPHY (Continued)

41. Anonymous, "Materials for the New Technologies," Metal Progress, April 1963, pp 9-12.

42. Johnson, C. J., "Hot Fuel for a Hot Aircraft," Materials Research & Standards, ASTM, 3, No. 4, April 1963, p 300.

APPENDIX A

Alphabetical List of Organizations Contacted from 1 July 1962 through 31 May 1963. An asterisk marks those organizations that responded to our inquiry..

Accurate Anodizing Corporation
4100 West Lake Street
Chicago 24, Illinois

Ace Laboratories
1620 Coutant Ave.
Lakewood, Ohio

* Acheson Colloids Co.
A Division of Acheson Industries, Inc.
Port Huron, Michigan

Adolph Plating, Inc.
840 S. Central Ave.
Chicago, Illinois

Advance Glove Mfg. Co.
962 W. Lafayette
Detroit, Michigan

* Aero Research
315 N. Aberdeen St.
Chicago 7, Illinois

Aerojet-General Corporation
Structural Materials Division
6352 North Irwindale Street
Azusa, California

* Aeronautical Systems Division
Nonmetallic Materials Laboratory
Wright-Patterson Air Force Base
Ohio

* Air Reduction Sales Company
Division of Air Reduction Co., Inc.
Equipment Engineering & Special Products Dept.
P.O. Box 281
Union, New Jersey

* Allegheny-Ludlum Corp
R and D Laboratories
Attn: Mr. Ray A. Lula
Brackenridge, Pennsylvania

Allegheny Plastics, Inc.
Route 51 and Thorn Run Road
Coraopolis, Pennsylvania

* Alliance Industrial Products Co.
4754 W. Washington
Chicago, Illinois

* Allied Chemical Corporation
Solvay Process Division
61 Broadway
New York 6, New York

Allied Chemical Corporation
Plastics Division
Dept. TR; 42 Rector
New York, New York

Allied Research Products, Inc.
4004-06 East Monument St.
Baltimore 5, Maryland

* Alloy Surfaces Co., Inc.
100 South Justison Street
Wilmington 1, Delaware

Almco Steel Products Corporation
Wabash Avenue
Bluffton, Indiana

* Alon Processing, Inc.
Box 11431-C
Pittsburgh, Pennsylvania

Alumatone Corp.
Grande Vista Ave. and E. Pico
Los Angeles, California

Amchem Products, Inc.
Box 33
Ambler, Penn.

* Amercoat Corp.
4809 Firestone Blvd., Dept. T.
South Gate, California

* American Cyanamid Co.
Plastics and Resins Division
Wallingford, Connecticut

American-Marietta Co.
Presstite Div.
3948 Chouteau Ave.
St. Louis, Missouri

American Metaseal Corporation
504 Washington Ave.
Carlstadt, New Jersey

American Nickeloid Co.
2nd and West Streets
Peru, Illinois

* American Potash and Chem. Corp.
W. 6th St. at Virgil
Attn: Dr. K. R. Eilar
Whittier Research Lab
Los Angeles 54, California

Amer. Rad. and Stand. Sanitary Corp.
Advance Technology Laboratories Div.
315 North Aberdeen St.
Chicago 7, Illinois

* American Smelting and Refining Co.
120 Broadway
New York 5, New York

* Anaconda Aluminum Co.
Sub. of Anaconda Co.
P. O. Box 1654
Louisville 1, Kentucky

* Anaconda American Brass Co.
Waterbury 20, Connecticut

Anderson Prichard Oil Co.
1002 Liberty Land Bldg.
Oklahoma City, Oklahoma

* Apco Oil Corporation
Liberty Bank Building
Oklahoma City 2, Oklahoma

* Arbonite Corporation
N. Main at Cross Keys
Doylestown, Penn.

Arco Company
Bessemer and Clarke Streets
Cleveland, Ohio

* Arizona, University of
Attn: C. S. Marvel
Tucson, Arizona

* Armco Steel Corporation
703 Curtis Street
Middletown, Ohio

John L. Armitage and Co.
239 Thomas
Newark, New Jersey

Armour Research Foundation
10 West 35th Street
Attn: J. J. Rausch
Chicago 11, Illinois

Armour Research Foundation of
Illinois Institute of Technology
Technology Center
10 West 35th Street
Chicago 16, Illinois

* Armstrong Cork Co.
1010 Concord
Lancaster, Penn.

* Army Research Office, Durham
Box CM, Duke Station
Durham, North Carolina

Arrow-Metal Products Corp.
Third Avenue
Haskell, New Jersey

Ashtabula Mfg. Company
West 30th Street
Ashtabula, Ohio

* Atlantic Laboratories of Delaware, Inc.
Box 1644
Wilmington, Delaware

Atlantic Steel Company
P.O. Box 1714
Atlanta 1, Georgia

Atlas Mineral Products Co.
121 Norman
Mertztown, Penn.

Atlas Powder Co.
Zapon Division
North Chicago, Illinois

Avco Manufacturing Co.
Avco Everett Research Lab
Everett, Mass.

Avco Corporation
RAD Division
750 Third Avenue
New York 17, New York

B. B. Chemical Co.
784 Memorial Drive
Cambridge, Mass.

BFLO Flame Spray & Machine Co. Inc.
236 Woodward Avenue
Buffalo, New York

M. E. Baker Company
25 Wheeler Street
Cambridge 38, Mass.

Barreled Sunlight Paint Co.
123 Georgia Ave.
Providence, Rhode Island

Barrett Chemical Products, Inc.
Shelton, Connecticut

Barrows Porcelain Enamel Corp.
Langdon and Wiehe Rd.
Cincinnati, Ohio

Gordon Bartels Co.
2602 Harrison Ave.
Rockford, Illinois

Battelle Memorial Institute
Attn: Mr. Cloyd Snavely
Chemical Engineering Div.
Columbus, Ohio

* Battelle Memorial Institute
Defense Metals Information Center
505 King Avenue
Columbus 1, Ohio

* Bauer Bros. Co.
1717 Sheridan Ave.
Springfield, Ohio

* Belding Corticelli Industries
533 7th Ave.
New York, New York

Belke Manufacturing Co.
951 N. Cicero Avenue
Chicago, Illinois

Berry Asphalt Co. of Arkansas
Box 800
Magnolia, Arkansas

* Bethlehem Steel Co.
Bethlehem, Penn.

Bevan Company
400 North Arden Drive
El Monte, California

* Bishopric Products Co.
4414 Este Ave.
Cincinnati, Ohio

Bisonite Co., Inc.
2248 Military
Buffalo, New York

* Boeing
Military Aircraft Systems Division
Wichita, Kansas

Bonafide-Genasco Inc.
New York, New York

Bordon Chemical Co.
A Division of the Bordon Co.
Dept. T
350 Madison Ave.
New York, New York

Borne Chemical Co., Inc.
632 S Front
Elizabeth, New Jersey

Breineg Bros., Inc.
125 Grand
Hoboken, New Jersey

Bridgeport Brass Co.
Bridgeport 2, Connecticut

Brightly Galvanized Products, Inc.
3308 S. Cicero Ave.
Cicero, Illinois

* The British Iron and Steel
Research Association
Sketty Hall Laboratories
Swansea, South Wales
Great Britain

Brunswick Corporation
Defense Products Division
1700 Messler Street
Muskegon, Michigan

* Cadillac Plastic & Chemical Co.
15111 Second Avenue
Detroit, Michigan

* California, University of
Attn: Dr. Anton Burg
Berkeley, California

Calorizing Co.
Hill & Pitt Streets
Wilkinsburg Station
Pittsburgh, Penn.

Carbozite Protective Coatings
24-13 Bridge Plaza N.
Long Island City, New York

* Carborundum Co.
Refractories Div.
Dept. MD-7R
Perth Amboy, New Jersey

Carey Philip Mfg. Co.
Wayne Ave. at Cooper
Cincinnati, Ohio

* Catalin Corp. of America
1 Park Ave.
New York, New York

* Ceilcote Co.
4933 Ridge Road
Cleveland, Ohio

* Celanese Polymer Co.
Div. of Celanese Corp. of America
744 Broad Street
Newark, New Jersey

* Ceramco, Inc.
171 Ridge
Newark, New Jersey

Chance-Vought Aircraft Co.
9314 West Jefferson
Dallas 22, Texas

Chemical Coatings and
Engineering Co., Inc.
221 Brooke Street
Media, Pennsylvania

Chemical Concentrates
Division of Baker Industries, Inc.
Fort Washington, Penn.

Chemical Products Corp.
10 King Philip Road
East Providence, Rhode Island

Chemstrand Research Center, Inc.
Attn: M. R. Lilyquist and
J. R. Holsten
Durham, North Carolina

Cheesman-Elliot Co., Inc.
645 Kent Avenue
Brooklyn, New York

Chicago Bridge and Iron Co.
1500 N. 50th St.
Birmingham, Alabama

Chicago Bridge and Iron Co.
332 S. Michigan Ave.
Chicago, Illinois

* Chromalloy Corp.
West Nyack, New York

* Circle Chemical Co.
333 North Michigan Ave.
Chicago 1, Illinois

Cleveland Hard Facing, Inc.
3049 Stillson Ave.
Cleveland, Ohio

Cleveland Metal Products Co.
Washington and Lenter Streets
Cleveland 1, Ohio

Clinton Company
1230 Elston Ave.
Chicago, Illinois

Clover Leaf Paint & Varnish Corp.
43rd and Vernon Blvd.
Long Island City, New York

* Columbia Technical Corp.
24-32 Brooklyn Queens Express-
way W.
Woodside, New York

Colonial Alloys Co.
Ridge and W. Crawford Streets
Philadelphia, Penn.

Continental Coatings Corp.
17706 Miles Avenue
Cleveland, Ohio

* Conversion Chemical Corp.
103 E. Main Street
Rockville, Connecticut

Coopers Creep Chemical Corp.
99 River
West Conshohocken, Penn.

Cordo California Corporation
10 W. Golden Triangle Road
Saugus, California

Cranz, J. M. Co., Inc.
Main and Amherst Streets
Buffalo, New York

Crucible Steel Co. of America
P. O. Box 2518
Pittsburgh 30, Pennsylvania

Crystal X Corporation
West Lenni Road
Lenni Mills, Pennsylvania

Dacar Chemical Products Co.
Wabash and McCartney Streets
Pittsburgh, Penn.

* Dampney Co.
60 Business Street
Hyde Park
Boston, Massachusetts

* Dearborn Chemical Co.
Merchandise Mart Plaza
Dept. TR
Chicago 54, Illinois

* Desoto Chemical Coatings, Inc.
1350 South Kostner
Chicago, Illinois

Detrex Chemical Industries, Inc.
Box 501
Detroit, Michigan

* Dewitt Plastics
Auburn, New York

DeWitt Products Co.
5858 Plumer
Detroit, Michigan

Diamond Alkali Company
300 Union Commerce Bldg.
Cleveland 14, Ohio

* Doehler-Jarvis Division
National Lead Co.
Research & Engineering Dept.
Toledo 1, Ohio

* Dore, John L. Co., Inc.
5602 Schuler Street
Houston 7, Texas

* Douglas Aircraft Co., Inc.
Charlotte Division
1820 Statesville Ave.
Charlotte, North Carolina

* Dow Chemical Co.
1000 Main
Midland, Michigan

* Dow Corning Corporation
Product Engineering Laboratories
Midland, Michigan

Dyna-Therm Chemical Corp.
3813 Hoke Ave.
Culver City, California

* E. I. duPont de Nemours and Co., Inc.
Electrochemicals Dept.
duPont Building
Wilmington, Delaware

* E. I. duPont de Nemours and Co., Inc.
Electrochemicals Dept.
Attn: Mr. A. J. Deyrup
350 5th Ave.
New York 1, New York

* E. I. duPont de Nemours and Co., Inc.
Explosives Dept.
Eastern Laboratory
P. O. Box B
Gibbstown, New Jersey

* E. I. duPont de Nemours and Co., Inc.
Finish Sales Division
1737 Ellsworth Industrial Dr., N. W.
Atlanta 18, Georgia

* E. I. duPont de Nemours and Co., Inc.
Industrial and Biochemical Dept.
Chestnut Run
Wilmington 98, Delaware

* E. I. duPont de Nemours and Co., Inc.
Marshall Laboratory
34th and Grays Ferry Ave.
Philadelphia 46, Pennsylvania

ERDL, Materials Branch
Attn: Mr. Emil York
Fort Belvoir, Virginia

Eagle Picher Co.
959 American Building
Cincinnati, Ohio

* Eastman Chemical Products, Inc.
Plastics Division
Kingsport, Tennessee

* Egyptian Lacquer Mfg. Co.
1268 6th Avenue
New York, New York

* The Electric Autolite Co.
Woodstock, Illinois

* Electro-Chemical Engr. & Mfg. Co.
Broad and Payne Streets
Allentown, Pennsylvania

Electrofilm, Inc.
7116 Laurel Canyon Blvd.
North Hollywood, California

Electrolizing Co.
1505 East End Avenue
Chicago Heights, Illinois

Eltex Research Corp.
43 Seekonk
Providence, Rhode Island

Emerson Electric Mfg. Co.
9100 Florissant Ave.
St. Louis 36, Missouri

* The Enamel Products Co.
341 Eddy Road
Cleveland 8, Ohio

* Enamel Products and Plating Co.
3500 Walnut
McKeesport, Pennsylvania

Enamelstrip Corp.
Sub. of National Steel Corp.
20th and Hamilton Streets
Allentown, Pennsylvania

* Enjay
15 West 51st Street
New York 19, New York

* Enthone, Inc.
442 Elm Street
New Haven 8, Connecticut

Esco Corp.
2141 N. W. 25th Avenue
Portland 10, Oregon

* Ethyl Corporation
Research Lab
Attn: Dr. S. Blitzer
Baton Rouge, Louisiana

* Falcon Corporation
G. P. O. Box 1035
Brooklyn 1, New York

* Ferro Corporation
4150 East 56th Street
Cleveland 5, Ohio

Fibre Glass-Evercoat Co., Inc.
Kugler Mill Road
Cincinnati, Ohio

Firestone Tire & Rubber Co.
Xylos Rubber Division
1300 Emerling Avenue
Akron, Ohio

Flexrock Company
3600-A Cuthbert
Philadelphia, Penn.

* Flintkote
Research Laboratory, Box 157
Whippany, New Jersey

Flood and Conklin Mfg. Co.
150 Chestnut
Newark, New Jersey

* The Fluorocarbon Co.
1754 South Clementine Street
Anaheim, California

Fluoro-Plastics, Inc.
Division of Flexrock Co.
36th and Filbert Streets
Philadelphia 1, Pennsylvania

* Foster, Benjamin Co.
4600 W. Girard
Philadelphia, Penn.

H. B. Fuller
1148 Eustis
St. Paul, Minnesota

* The Galigher Co.
545 West 8th Street
Salt Lake City 10, Utah

* Galvicon Corp.
22 Meadow Street
Brooklyn 6, New York

Garfield Mfg. Co.
12 Midland Ave.
Wallington, New Jersey

Garland Co.
3800 E. 91st Street
Cleveland, Ohio

* Gates Engineering Co.
58 Kern Avenue
Wilmington, Delaware

* General American Transportation Corp.
Kanigen Division
135 South Lasalle Street
Chicago 3, Illinois

General Coating, Inc.
Eastern Sub of Heresite and Chem. Co.
405 Main
Woodbridge, New Jersey

* General Electric Co.
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Schenectady, New York

General Electric Co.
Attn: J. B. Levy
Schenectady, New York

General Electric Co.
Attn: Leonard Maisel
Schenectady, New York

* General Electric Co.
Chemical Materials Dept.
Section MDE-71
Pittsfield, Mass.

* General Electric Co.
Attn: S. J. Beyer
Louisville, Kentucky

* General Electric Co.
Silicone Products Dept.
Mechanicsville Road
Waterford, New York

* General Electric Research Lab
570 Lexington Ave.
New York, New York

General Motors Corp.
Rochester Products Div.
Rochester, New York

General Telephone & Electronics
730 Third Ave.
New York, New York

* General Telephone & Electronics
Bayside Laboratories
Bayside 60, New York

* Glidden Company
900 Union Commerce Building
Cleveland, Ohio

B. F. Goodrich Co.
Aerospace and Defense Products
500 S. Main Street
Akron, Ohio

* Goodyear Tire & Rubber Co., Inc.
1144 E. Market
Akron, Ohio

Gottlieb Chemical Co.
8054 Barnes
Detroit, Michigan

* Grunwald Plating Co., Inc.
21st at Rockwell
Chicago, Illinois

* A. Gusmer, Inc.
Stalpic Division
Prospect and Barron Avenues
Woodbridge, New Jersey

Harshaw Chemical Co.
1945 East 97th Street
Cleveland 6, Ohio.

Houghton Laboratories, Inc.
4151 Russell
Olean, New York

* Haynes Stellite Co.
1020 West Park Avenue
Kokomo, Indiana

* Heatbath Corp.
P. O. Box 78
Springfield 1, Mass.

* Heresite & Chemical Co.
822 S. 14th Street
Manitowoc, Wisconsin

Hooker Chemical Corp.
Durez Plastics Division
17 Walck Rd.
North Tonawanda, New York

A. C. Horn Companies
Division of Sun Chemical Corp.
750 Third Avenue
New York, New York

Hub Paint and Varnish Co., Inc.
47-38 Fifth Avenue
Long Island City, New York

Hughson Chemical Company
A Division of Lord Mfg. Co.
Erie, Penn.

* Humble Oil & Refining Co.
8230 Stedman Street
Houston 29, Texas

* Illinois, University of
Attn: Dr. John C. Bailar
Urbana, Illinois

* Industrial Metal Protectives, Inc.
400 Homestead Ave.
Dayton, Ohio

* International Nickel Co., Inc.
Attn: R. Vines
New York, New York

International Silver Co. Laboratory
Attn: Mr. Malcolm Orr
Meriden, Connecticut

Irco Corporation, Engineering
16 Hudson
New York, New York

Jamestown Finishes, Inc.
52 Angove
Jamestown, New York

Joclin Mfg. Co.
15 Lufbery Ave.
Wallingford, Connecticut

* Johns-Manville
22 East 40th
New York, New York

Jones and Laughlin Steel Corp.
3 Gateway Center
Pittsburgh 30, Pennsylvania

* Kaiser Aluminum and Chemical Corp.
Dept. of Metallurgical Research
Spokane 69, Washington

* Kaiser Aluminum & Chemical Sales, Inc.
919 Michigan Avenue
Chicago 11, Illinois

Kelite Corporation
77 Industrial Road
Berkeley Heights, New Jersey

Kelly Mfg. Co.
4800 Clinton Drive
P.O. Box 17
Houston 1, Texas

Kennametal, Inc.
Lloyd Avenue
Latrobe, Pennsylvania

Kish Industries, Inc.
Turner at Kish
Lansing, Michigan

* Knight, Maurice A.
171 Kelly Avenue
Akron, Ohio

* Koppers Co., Inc.
Tar Products Division
Koppers Bldg.
Pittsburgh, Penn.

Kosmos Electro-Finishing Res., Inc.
140 Liberty Street
Hackensack, New Jersey

Lancaster Chemical Corp.
13th and Broad Streets
Carlstadt, New Jersey

Leon Chemical Industries
862 Grandville at Nicholas Sq.
Grand Rapids, Michigan

* Libbey-Owens-Ford
Liberty Mirror Division
23111 Libbey-Owens-Ford Bldg.
Toledo 1, Ohio

Light Metal Processors, Inc.
3436 W. Henderson
Chicago, Illinois

* Linde Company
Attn: Mr. H. V. Mosby
Speedway Factory
4801 West 16th Street
Indianapolis 24, Indiana

* Lion Oil Co.
Division of Monsanto Chemical Co.
El Dorado, Arkansas

Lithcote Corp.
5002 W. Lake
Melrose Park, Illinois

* Litho-Strip Corporation
4800 S. Kilbourn Avenue
Chicago 32, Illinois

* Ludlow Plastics
Division of Ludlow Corp.
Dept. R-60
Needham Heights, Mass.

Maas and Waldstein Co.
2121 McCarter Highway
Newark, New Jersey

MacDermid, Inc.
526 Huntingdon Ave.
Waterbury 20, Conn.

Magic Chemical Co.
123 Crescent
Brocton, Mass.

Magna-Bond, Inc.
12 Union Ave.
Bala Cynwyd, Penna.

Marblette Corp.
The Marblett Building
30th Street
Long Island City, New York

* Markal Company
3070 W. Carroll Ave.
Chicago 12, Illinois

* Martin Company
Baltimore, Maryland

* Martin Co.
Denver Division
P. O. Box 179
Denver, Colorado

Meadows, Inc., W. R.
No. 4 Kimball
Elgin, Illinois

* Mearl Corp.
39-41 E. 42nd
New York, New York

Mechanical Plating Company
1500-26 West Hubbard Street
Chicago 22, Illinois

* Mellon Institute
Attn: E. F. Casassa
4400 5th Ave.
Pittsburgh, Penn.

Metal and Thermit Corp.
Rahway, New Jersey

Metal-Cladding, Inc.
P. O. Box 544
North Tonawanda, New York

* Metal Coating Corp.
1201 W. 37th St.
Chicago, Illinois

Metal Finishes, Inc.
Cleveland, Ohio

Metal Finishing Supply, Inc.
322 West 2nd
East Syracuse, New York

Metallizing Co. of America, Inc.
Dept. TR 3520
3520 W. Carroll Ave.
Chicago, Illinois

* Metallizing Co. of Los Angeles, Inc.
1233 South Boyle Avenue
Los Angeles 23, California

Metallizing Industries, Inc.
339 Hudson St.
Hackensack, New Jersey

Metalplate
757 N. 44th
Birmingham, Alabama

Metals and Controls, Inc.
34 Forest Street
Attleboro, Mass.

Metalweld, Inc.
3201 Scotts Lane
Philadelphia, Penn.

Metasurf Corp.
14350 Cloverdale Ave.
Detroit 38, Michigan

* Metco, Inc.
1105 Prospect Ave.
Westbury, L. I., N.Y.

Michigan Chrome and Chemical Co.
8615 Grinnell Ave.
Detroit, Michigan

* Midland Industrial Finishes Co.
Waukegan, Illinois

* Midwestern Color Works, Inc.
Minneapolis, Minnesota

* Minnesota Mining and Mfg. Co.
1000 Bush Avenue
St. Paul, Minnesota

* Minnesota Mining and Mfg. Co.
Missile Industry Liaison 21-2E
900 Bush Avenue
St. Paul 6, Minnesota

* Mitchell-Bradford Chemical Co.
Wampas Lane
Milford, Connecticut

Modern Plating Corporation
121-129 South Hancock Avenue
Freeport, Illinois

Monsanto Chemical Co.
Plastics Division
St. Louis 66, Missouri

* J. W. Mortell Co.
582 Burch
Kankakee, Illinois

Munray Products, Inc.
Division of Fanner Mfg. Co.
12388 Crossburn Ave.
Cleveland, Ohio

* McDonnell Aircraft Corporation
1707 H. Street, N. W.
Los Angeles 54, California

McDougall-Butler Co., Inc.
Main and Huntington Galleries
Buffalo, New York

National Bureau of Standards
Attn: M. E. Wacks
Connecticut Ave. & Van Ness St. N. W.
Washington 25, D. C.

* National Glaco Chemical Co.
Industrial Coatings Division
A Division of Ekco Products Co.
1949 N. Cicero Ave.
Chicago, Illinois

National Lock Co.
1902 7th Street
Rockford, Illinois

National Mfg. Corp.
3343 Flanagan
Tonawanda, New York

* National Research Corp.
70 Memorial Drive
Cambridge, Mass.

* National Starch and Chem. Corp.
750 Third Avenue
New York, New York

* Dept. of the Navy
Bureau of Ships
Washington 25, D. C.

* Dept. of the Navy
Bureau of Naval Weapons
Washington 25, D. C.

G. J. Nikolas & Co., Inc.
2870 Washington
Bellwood, Illinois

Northwest Chemical Co.
9300 Roselawn Ave.
Detroit, Michigan

* Norton Co.
Refractories Division
346 New Bond Street
Worcester 6, Massachusetts

* Nuclear Materials & Equip. Corp.
Apollo, Penn.

Nuclear Metals, Inc.
West Concord, Massachusetts

Nukem Products Corp.
110-120 Colgate Ave.
Buffalo, New York

* Nylock Corporation
611 Industrial Avenue
Paramus, New Jersey

Oakite Products, Inc.
46-A Rector
New York, New York

Ohio Sealer & Chemical Corp.
2029 S. Springboro Road
Dayton, Ohio

Ohio State University Research Foundation
Columbus, Ohio

Ornamental Plastics, Inc.
Fluorocarbon Div.
19th at Oakland
Sheboygan, Wisconsin

* Panther Chemical Co.
824 N. Main
Fort Worth, Texas

Parker Rust Proof Co.
2173 E. Milwaukee
Detroit 11, Michigan

* Parker Rustproof Division
Hooker Chemical Corp.
2169 E. Milwaukee Ave.
Detroit, Michigan

Parr Paint and Color Co.
Syracuse & Brussels Road
Cleveland 10, Ohio

Penn Galvanizing Co.
2199 E. Tioga
Philadelphia, Penn.

* Pennsylvania Fluorocarbon Co.
1115 North 38th Street
Philadelphia 4, Pennsylvania

Permiteco, Inc.
1102 E. Monument Ave.
Dayton, Ohio

* Pfaudler Co.
Div. of Pfaudler Permutit, Inc.
West Ave. and Clark
Rochester, N. Y.

* Phillips Chemical Co.
Plastics Sales Division
Bartlesville, Oklahoma

* Pierce & Stevens Chemical Corp.
724 Ohio
Buffalo, New York

* Pittsburgh Coke & Chemical Co.
1970 Grant Bldg.
Pittsburgh, Penn.

* Pittsburgh Plate Glass Co.
Paint Division
One Gateway Center
Pittsburgh, Penn.

Pittsburgh Steel Co.
P.O. Box 118
Pittsburgh 19, Pennsylvania

* Plasmadyne Corp.
3839 South Main Street
Santa Ana, California

Plastic Coating Corp.
Holyoke, Mass.

Platecraft of America Co.
CEM Division
570 Tifft Street
Buffalo 20, New York

* Polymer Corp.
Reading, Penn.

H. K. Porter Co. Inc.
National Electric Division
1401 Porter Building
Pittsburgh, Penn.

* Pratt & Whitney Aircraft
Division of United Aircraft Corp.
East Hartford 8, Connecticut

* Pratt & Whitney Aircraft Div.
Turner A. Sims Defense Bldg.
1026 17th St. N.W.
Washington 6, D.C.

Pre-Finish Metals
Elk Grove Village, Illinois

* Pro-Chem Co., Inc.
130 W. 31st Street
New York, New York

Pyroxylin Products, Inc.
4853 S. St. Louis Ave.
Chicago, Illinois

* Puget Sound Fabricators, Inc.
3670 East Marginal Way
Seattle, Washington

* Puma Corporation
P.O. Box 82
Farmingdale, Long Island, N.Y.

Pyro-Metal Finishes Division
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Newark, New Jersey

Quelcor, Inc.
1200 W. Front
Chester, Penn.

* Raffi and Swanson, Inc.
Wilmington, Mass.

* Raybestos-Manhattan, Inc.
Reinforced Plastics Dept.
Manheim, Penn.

Raytheon Co.
Aero Weapons Div.
Spring Street
Attn: T. C. Wisenbaker, V.P.
Mgr. Aero Weapons Div.
Lexington, Mass.

* Reichhold Chemicals, Inc.
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White Plains, New York

Reilly Tar and Chemical Corp.
1620 Merchants Bank Bldg.
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Associate Editor
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430 Park Ave.
New York 22, New York

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5424 S. Cedar Road
Lansing, Michigan

* Republic Steel Corporation
Dept. ME-3960
1441 Republic Building
Cleveland, Ohio

Republic Steel Corporation
Research Laboratories
Attn: Mr. R. Place
Canton, Ohio

* Reynolds Metal Co.
P.O. Box 2346-ZA
Richmond, Virginia

Rockwell Engineering Co.
13500 South Western Avenue
Blue Island, Illinois

H. H. Robertson
2407 Farmers Bank Bldg
Pittsburgh, Penn.

Rohm and Haas Co.
Plastics Division
Philadelphia 5, Penn.

Rubber Corp. of America
New South Road
Hicksville, New York

W. J. Ruscoe Co.
479 Kenmore Blvd.
Akron, Ohio

* Rust-Oleum Corp.
2430 Oakton St.
Evanston, Illinois

Rust-Sele Co.
9814 Meech Ave.
Cleveland, Ohio

* Rustproofing and Metal Finishing Corp.
75 Commercial Avenue
Cambridge 42, Mass.

Rysgaard Co.
1260 W. Connelly
St. Paul, Minn.

Sanitary Corporation
Advanced Technology Laboratories Div.
315 N. Aberdeen St.
Chicago 7, Illinois

Schenectady Varnish Co., Inc.
3303 Congress
Schenectady, New York

* Seal-Peel, Inc.
775 Stephenson Highway (Detroit)
Troy, Michigan

* Seaporcel Metals, Inc.
Borden Ave. and Dutchkills
Long Island City, New York

Servwell Products Co.
6521 Euclid Ave.
Cleveland, Ohio

* Sheldon, M. L. and Co., Inc.
350 Lexington Avenue
New York 16, New York

* Shell Chemical Co.
Division of Shell Oil Co.
6054 W. Touhy Ave.
Chicago 48, Illinois

* James B. Sipe and Co.
115 Vanadium Rd.
Pittsburgh, Penn.

Sinclair & Valentine Co.
611 W. 129th
New York, New York

* Solar Aircraft Company
2200 Pacific Highway
San Diego 12, California

* Sonneborn Chemical & Refining Corp.
404 Park Ave., S., Dept. T-60
New York, New York

Southern Metal Products Co.
4444 North Miro Street
New Orleans 17, Louisiana

* Southern Research Institute
Attn: Dr. R. S. Burks
Birmingham 5, Alabama

* Southwest Research Institute
8500 Culebra Road
San Antonio, Texas

Speco, Inc.
7312 Associates Ave.
Cleveland 9, Ohio

W. L. Spencer Co.
1691 W. Water
Milwaukee, Wisconsin

Stalpic, Inc.
Montclair, New Jersey

* Standard Dry Wall Products, Inc.
77 Hudmont
New Eagle, Penn.

* Standard Metals Corp.
262 Broad Street
North Attleboro, Massachusetts

Stanley Chemical Company
77 Berlin
East Berlin, Conn.

* Steel Protection & Chemical Co.
Mooresville, Indiana

Stevens Institute
Hoboken, New Jersey

St. Louis Metallizing Co.
623 S. Sarah
St. Louis, M ssouri

* Stoner-Mudge, Paint & Chem. Div.
of Martin-Marietta
2000 Westhall St.
Pittsburgh, Pennsylvania

Strathmore Products, Inc.
W. Lafayette at Harbor
Syracuse, New York

Sun Steel Co.
Special Products Division
1700 W. 74th Place
Chicago 36, Illinois

Superior Plating, Inc.
University and 1st Avenue, N. E.
Minneapolis 13, Minnesota

* Superior Steel Division of
  Copperweld Steel Co.
  Main Street
  Carnegie, Penn.

Swedlow, Inc.
6986 Bandini Blvd.
Los Angeles, California

Sylvania Electric Products, Inc.
1740 Broadway
New York 19, New York

Sylvester and Co.
17706 Miles Ave.
Cleveland, Ohio

* Syracuse University
  Research Institute
  Collendale Campus
  Syracuse 10, New York

Syracuse University
L. C. Smith College of Engineering
Syracuse 10, New York

Tapecoat Co.
1525 Lyons
Evanston, Illinois

Tech Industro Co.
W. Pike and Lawrence Sts.
Philadelphia, Penn.

Tejas Plastics Materials Supply Co.
P.O. Box 11302
Fort Worth, Texas

Testworth Laboratories, Inc.
Addison Industrial Area
Addison, Illinois

Texas Instruments, Inc.
Metals and Controls Div.
1607 Forest St.
Attleboro, Mass.

* Thermal Dynamics Corp
  300 Mechanic St.
  Lebanon, New Hampshire

Thermal Refractories Corp.
4501 Dell Avenue
North Bergen, New Jersey

* Thermo-Bonded Plastic Coatings, Inc.
  2424 St. Road
  Cornwells Heights, Penn.

Thompson and Co.
Div. of Benjamin Moore & Co.
1085 Edwards Blvd.
Oakmont, Penn.

Thompson-Ramo-Wooldridge
TAPCO
23444 Euclid Ave.
Cleveland 17, Ohio

* Arthur Tickle Engineering Works, Inc.
  21-29 Delevan St.
  Brooklyn 31, New York

* Timken Roller Bearing Co.
  Steel and Tube Division
  Canton 6, Ohio

* Titanine Division
  Seagrave Corporation
  Elmwood & Morris Avenues
  Union, New Jersey

* Titanium Alloy Mfg.
  Div. of National Lead Co.
  111 Broadway
  New York, New York

Tropical Paint Co.
Sub. of Parker Rust Proof Co.
1210-1250 W. 70th
Cleveland, Ohio

Tuff Clad, Inc.
West Oak Street Extension
Kent, Ohio

Turco Products, Inc.
24600 South Main St.
Wilmington, California

Tylene Plastics Co.
Div. Armstrong Resins, Inc.
P.O. Box 1-T
Warsaw, Indiana

* Udylite Corp.
Detroit, Michigan

* Union Carbide Corporation
Linde Company
270 Park Ave.
New York 17, New York

Union Carbide Corporation
Research & Develop. Lab.
61 East Park Drive
Tonawanda, New York

* Union Carbide Corporation
Silicones Division
270 Park Ave.
New York 17, New York

Union Carbide Metals Co.
Division of Union Carbide Corp.
270 Park Avenue
New York 17, New York

United Technical Laboratories
202 Littleton Road
Morristown, New Jersey

* United States Rubber Co.
Mechanical Goods Division
1232 Avenue of the Americas
New York, New York

Uniworld Research Corp. of America
9802 Euclid Avenue
Cleveland 6, Ohio

Upson Chemical Corp.
43 Upson Point
Lockport, New York

* U. S. Polymeric Chemicals, Inc.
Ludlow Street
Stamford, Connecticut

Valley Metallurgical Processing Co.
Plasmatech Division
Route 9
Essex, Conn.

* Vanadium-Alloys Steel Co.
Latrobe, Pennsylvania

Vanamatic Co.
204 South Jefferson Street
Delphos, Ohio

Vulcan Division
Reeves Brothers, Inc.
1071 Avenue of the Americas
New York, New York

* Vita-Var Company
48 Albert Ave.
Attn: Mr. Carl Frey
Newark, New Jersey

* Wall Colmonoy Corp.
19345 John R. Street
Detroit 3, Michigan

* T. F. Washburn Co.
2244 Elston Ave.
Chicago, Illinois

Watertown Arsenal
Watertown 72, Mass.

Watson Standard Co.
225 Galveston Ave.
Pittsburgh, Penn.

Weatherguard Products Corp.
2341-A Chatterton Ave.
New York, New York

* Western Coating Co.
Box 598, Oakridge Station
Royal Oak 3, Michigan

Wilcox-Crittenden
Div. of North & Judd Mfg. Co.
55 S. Main
Middletown, Conn.

Wilson, H. A., Co.
Div. of Engelhard Industries Inc.
2655 U. S. Route 22
Union, New Jersey

Lee Wilson Engineering Co., Inc.
20005 Lake Road
Cleveland, Ohio

Wyandotte Chemicals Corp.
J. B. Ford Division
Wyandotte, Michigan

* Youngstown Mfg. Inc.
66-76 S. Prospect St.
Youngstown, Ohio

Zophar Mills, Inc.
100 26th St.
Brooklyn, New York

* Zirconium Corp. of America
31501 Solon Road
Solon, Ohio

APPENDIX B

Letter and Questionnaire Sent to 396 Coating Manufacturers, Manufacturing Companies Interested in Coatings, Research Organizations, Government-Related Industries, and Governmental Agencies

Southern Research Institute

2000 NINTH AVENUE SOUTH
BIRMINGHAM 5, ALABAMA

As part of the joint effort of civilian and military government agencies to develop a practical supersonic-transport aircraft, Southern Research Institute is under contract to the National Aeronautics and Space Administration to conduct a survey and make a preliminary evaluation of all types of protective coatings that may serve to prevent corrosion of sheet metals that are being considered for application as a skin material. The first phase of our work is a screening program to determine which of the available coatings are most promising for the intended application. We are including for consideration any type of metallic, organic, or ceramic coating and any surface treatment for which we can obtain information from a literature search or from organizations such as yours.

The protective and other properties desired in the coatings are directly related to the design estimates of the service conditions to be encountered in supersonic-transport aircraft. It is estimated that the total service life of the aircraft will be approximately ten years with a minimum of 30,000 hours of operating time. Maximum loading and mechanical fatigue is expected to occur at temperatures near ambient during the ascent and descent portions of each flight. The maximum skin temperature of 650°F is expected to occur during the cruise portion of the flight under relatively stable loading conditions.

Between flights the aircraft will be subject to the normal weathering conditions to which present-day aircraft are exposed. Supersonic-transport aircraft must be competitive with conventional-transport aircraft, so the economic factors of first cost, maintenance, and ease of repair must also be given consideration.

In order to evaluate the suitability of the coatings for meeting service conditions, we plan to judge them on four criteria: 1) Inherent Stability—ability to retain their inherent properties over long periods of time under normal weathering conditions and to resist damage from abrasion, nicks, and scratches; 2) Thermal Stability—retention of their protective properties after repeated exposures to the extremes of temperatures (-100° F to 650° F) to be encountered in service; 3) Flexibility or Ductility—Ability to move and flex with the base metal over the full temperature range involved (-100° F to 650° F); and 4) Ease of Application and Repair—Amenability to economical first application and to maintenance and repair in the field.

We would greatly appreciate receiving any information you may be able to supply regarding possible candidate coatings manufactured by your organization. If you are not a manufacturer but have information on suitable coatings in production or development stages, we would appreciate any pertinent information that you can provide. In order to assist you in reporting the desired information we are enclosing several copies of a questionnaire. Please fill in a separate questionnaire for each coating material reported. Additional blank copies of the questionnaire will be supplied by us if you request them. Please feel at liberty to use the back of the questionnaire for additional or qualifying remarks if there is not enough space on the face. Copies of data sheets, brochures, or reference lists on the candidate coatings would also be welcomed.

Your cooperation in returning these questionnaires as soon as possible will be of great benefit to this program, and will contribute to the military and economic advancement of the United States. We extend our sincere thanks for any assistance you can offer.

Very truly yours,

S. G. Holder, Jr.

S. G. Holder, Jr.
Associate Metallurgist

sgh hmm
1417

Questionnaire

Protective Coating for Sheet Metals in

Supersonic Transport Aircraft

Southern Research Institute

2000 Ninth Avenue South

Birmingham 5, Alabama

Date ______________________

Submitted by: ______________________

____

____

1. Name of coating: ______________________

2. Manufacturer: ______________________

3. Availability (circle): Production Item Development Item

4. Usual Thickness: ______________

5. Quantity cost for application per sq ft of surface covered: ______________________

6. Corrosion protection, normal weather (circle): Good Fair Poor

7. Service temperatures for 30,000 hr operation: Minimum: ______________ Maximum: ______________

8. Resistance to temperature fluctuations (-100° F to 650° F) (circle): Good Fair Poor

9. Resistance to abrasion, nicks, and scratches (circle): Good Fair Poor

10. Flexibility (circle): -100° F: Good Fair Poor Ambient: Good Fair Poor 650° F: Good Fair Poor

11. Details of application procedure (Use back of page or separate sheet if necessary):

12. Can you supply minimum sample on 12 in. x 12 in. panel supplied by us? (circle): Yes No

13. If yes, on what terms?:

14. Additional remarks:

____

SOUTHERN RESEARCH INSTITUTE

APPENDIX C

Numerical Ratings of Coating Properties Determined by Use of the Industrial-Survey Rating System

In the following table, the left column of numbers are identifying numbers assigned to each coating as it was classified according to type. The same or similar types of coatings suggested by different companies were grouped under one coating number and are considered as one coating in the table. The trade name, company, and numerical values given each coating property are also presented in the table. The total score obtained by adding the numerical values of each coating property is shown, together with the standing of the coating within its own category of metallic, organic, semi-organic, inorganic, other (unclassified), or surface treatment.

Industrial-Survey Ratings of Coating Properties

No.	Type of Coating	Trade Name	Company	Numerical Values Given Coating Properties[1] (CP)	(MST)	(RTF)	(F650)	(FA)	(NST)	(F100)	(RA)	(EFA)	(AC)	(A)	Total	Category Standing
	METALLIC															
	Aluminum															
1	Electrophoretic & Rolled	Elphal Process	The British Iron & Steel Research Asso.	50	40	30	30	30	20	20	10	0	5	3	238	4
2	Flame Sprayed			50	40	30	15	30	20	10	10	5	10	6	226	8
		Flame Sprayed Aluminum (99.0%)	Metco, Inc.													
		Aluminum Metal Spraying	Metallizing Co. of Los Angeles													
40	Hot-Dip Aluminized	Aluminized Steel, Type II	Armco Steel Corp.	50	40	30	30	30	20	20	0	0	10	6	236	5
3	Vacuum Deposited			50	40	30	30	30	20	20	10	0	0	3	233	6
		Vapor Deposited Aluminum	Ethyl Corp.													
		Vacuum Deposited High Purity Aluminum	National Research Corp.													
	Aluminum Alloy															
4	Diffused Al-Fe			50	40	30	30	15	20	10	10	0	5	6	216	9
		Haynes Diffusion Coating No. C-10	Haynes Stellite Co.													
		Alonizing	Alon Processing, Inc.													
5	Diffused Al-Ni	Haynes Diffusion Coating No. C-3	Haynes Stellite Co.	50	40	30	30	15	20	10	10	0	5	6	216	9
	Chromium															
6	Diffused Cr	Chromalloy Type "G" Coating	Chromalloy Corporation	50	40	30	30	30	20	10	10	0	5	6	231	7
38	Diffused Cr	Alphatizing	Alloy Surfaces Co., Inc.	50	40	30	30	30	20	20	10	0	10	6	246	2
	Nickel															
7	Electroplated& Hot Rolled	Hot Rolled Nickel Coating	The International Nickel Co., Inc.	50	40	30	30	30	20	20	10	0	5	3	238	4
8	Electroplated Ni & Cd	Electroplated Coating of Nickel & Cadmium	The Boeing Co., Military Aircraft Systems Division	50	40	30	30	30	20	10	10	5	5	6	236	5
	Nickel Alloy															
9	Electroless	Kanigen Nickel Alloy	General American Transportation Corp.	50	40	30	0	0	20	0	10	0	5	6	161	11
10	Fused Ni-Cr	Nicrocoat	Wall Colmonoy Corp.	50	40	30	30	30	20	20	10	0	5	6	241	3

Industrial-Survey Ratings of Coating Properties (Continued)

No.	Type of Coating	Trade Name	Company	(CP)	(MST)	(RTF)	(F650)	(FA)	(NST)	(F100)	(RA)	(EFA)	(AC)	(A)	Total	Category Standing
				Numerical Values Given Coating Properties[1]												
	Zinc															
11	Cold Galvanized	Rust-Ban 191 "Galvicon" Compound	Humble Oil & Refining Co. Galvicon Corporation	50	40	30	30	30	20	20	10	10	10	6	256	1
12	Hot-Dip Galvanized	Hot-Dip Galvanized (Zinc)	Metal Coating Corporation	50	40	30	15	15	20	10	10	0	10	6	206	10
	Miscellaneous															
37	Explosively Bonded Stainless Steel, Nickel Alloy, or Titanium	Explosively Bonded Coating (R & D Item)	E. I. duPont de Nemours & Co., Inc.	50	40	30	30	30	20	20	10	0	5	3	238	4
	ORGANIC															
	Epoxy															
41	Chemically Cured Epoxy	Super Koropon Fluid Resistant Resistant Enamel	DeSoto Chemical Coatings, Inc.	50	0	30	15	30	20	15	10	10	10	6	196	5
13	Epoxy Resin	Vibro-Flo E-201 Epoxy Powder	Armstrong Resins, Inc.[2]	50	0	30	0	30	20	0	10	5	5	6	156	11
	Phenolic															
14	Teflon in Phenolic Resin	'Emralon' 310 (PTFE in Phenolic Resin	Acheson Colloids Co.	50	20	30	30	30	20	10	10	0	10	6	216	3
	Polymer															
44	Acrylic Copolymer	SX-228 High-Temperature Resistant Coating	Reichhold Chemicals, Inc.	50	0	15	30	30	10	10	10	0	10	3	168	10
15	Epoxy Polymer	Resiweld Protective Coating No. 224	H. B. Fuller Co.	50	0	15	30	30	20	15	8	10	10	6	194	6
42	Chemically Cured Polyurethane	DeSoto Polyurethane	DeSoto Chemical Coatings, Inc.	50	0	30	15	30	20	15	10	10	10	6	196	5
16	Thermosetting Polymer	GIC-805	National Glaco Chemical Co.	50	40	30	30	30	20	20	5	5	0	6	236	1
	Silicone															
17	Aluminum-Modified	XP-310 Heat Resistant Aluminum Paint	Dow Corning Corp.	50	20	30	15	15	10	10	5	10	10	3	178	9
18	Catalytically Cured Silicone Resin Vehicle	Catalytically Cured Silicones	Aeronautical Systems Division, Coatings Sec.	50	40	15	30	30	10	10	8	10	5	3	211	4
19		Vita-Var No. 16169 Heat Absorption Paint White Formulation PV100X	Vita-Var Co.	50	40	23	30	30	20	10	10	0	10	3	226	2
20	Teflon in Silicone Resin	EC-1697E (PTFE in Silicone Resin)	Acheson Colloids Co.	50	20	30	30	30	20	10	10	0	10	6	216	3

Industrial-Survey Ratings of Coating Properties (Continued)

No.	Type of Coating	Trade Name	Company	(CP)	(MST)	(RTF)	(F650)	(FA)	(NST)	(F100)	(RA)	(EFA)	(AC)	(A)	Total	Category Standing
				Numerical Values Given Coating Properties[1]												
	SEMI-ORGANIC															
	Polymer															
21	Silicon-Nitrogen Chains	Hexaphenylcyclotrisilazane-Ethylene-diamine Silazane Polymer Blend	Southern Research Institute	50	20	30	30	30	10	20	10	0	10	3	213	1
22	Silicon-Nitrogen Chains with Phenyl Groups Attached	Diphenyl Silazane Polymer	Southern Research Institute	25	20	15	15	15	10	10	5	5	10	3	133	3
23	Organophosphorus	Organophosphorus - Metal Oxide	Southern Research Institute	25	20	15	15	30	10	10	5	5	10	3	148	2
	INORGANIC															
	Aluminum Oxide															
24	Flame Sprayed	Rokide A Aluminum Oxide	Norton Company, C. M C. Corp.	50	40	30	30	30	10	10	10	10	0	6	226	2
	Cermet															
39	Aluminum and Ceramics	Alcermet S1177	Solar Aircraft Co.	50	40	30	30	30	10	10	10	10	0	6	226	2
	Fused Minerals															
25		Korok A-19	The Enamel Products Co.	50	40	30	30	30	20	20	10	0	10	6	246	1
	Non-Vitreous Ceramic															
26	Flame Sprayed	Standard Stock Production Material	Ceramco, Inc.	50	20	30	30	30	10	0	10	5	10	6	201	4
	Zinc Silicate			50	40	30	15	15	20	10	10	5	10	6	211	3
27		ZRAS Zincilate 101 Dimetcote No. 4 (No. 1731)	Koppers Company, Inc. Industrial Metal Protectives, Inc. Amercoat Corporation													

Industrial-Survey Ratings of Coating Properties (Continued)

No.	Type of Coating	Trade Name	Company	Numerical Values Given Coating Properties[1] (CP)	(MST)	(RTF)	(F650)	(FA)	(NST)	(F100)	(RA)	(EFA)	(AC)	(A)	Total	Category Standing
	OTHER															
28		A-61110-50 (Air craft White)	Rust-Oleum Corp.	50	40	15	15	15	20	10	10	5	10	6	196	5
29		"Connerkote"	Allegheny Ludlum Steel Corp.	25	40	30	30	30	10	10	5	0	10	3	193	6
30		Heat-Resistant Coating 57X50	Benjamin Foster Co.	50	40	30	30	30	20	10	10	10	10	6	246	1
31		Humiseal Type 1C40	Columbia Technical Corp.	50	40	30	15	30	10	10	5	0	10	6	206	4
32		Markal Protective Coating "DA-9" Aluminum	Markal Co.	50	40	30	30	30	20	10	10	10	10	6	246	1
33		"Pyre M. L." Varnish	E. I. duPont de Nemours & Co., Inc. Marshall Laboratory	50	20	30	30	30	20	20	5	0	10	6	221	3
43		3M High Temperature Elastomeric Coating	Minnesota Mining and Mfg. Co.	50	20	15	30	30	10	10	10	10	5	3	193	7
34		805-Titanine Division	Seagrave Corp., Titanine Division	50	40	30	30	30	20	20	10	0	10	3	243	2
	SURFACE TREATMENT															
35	Black Passivation	Black Magic SS Black Finish for Stainless Steels	The Mitchell-Bradford Chemical Co.	25	20	30	15	15	10	20	10	0	10	6	161	2
36	Graphite in Water	'Aquadag' (Graphite in Water)	Acheson Colloids Co.	25	40	30	15	30	20	10	5	0	10	6	191	1

[1]CP = Corrosion protection, MST = Maximum service temperature, RTF = Resistance to thermal fluctuations, F650 = Flexibility at 650° F, FA = Flexibility at ambient temperatures, NST = Minimum service temperature, F100 - Flexibility at -100° F, RA = Resistance to abrasion, nicks, and scratches, EFA = Ease of field application, AC = Cost of application, A = Availability, Underline = Our estimate.

[2]Recommended for special applications not related to the skin material.

APPENDIX D

Results of Experiments

In this table, the first column lists for each coating the number corresponding to the order in which the coatings were originally arranged for experimental evaluation. These numbers correspond to those in the first column of the table of detailed industrial-survey ratings found in Appendix C. The second column shows the major categories used to classify the coatings; namely, metallic, organic, semiorganic, inorganic, and other. The letters in the specimen numbers designate the type of exposure given to the 12 specimens of each coating. The numerals in the specimen number were used for identification during the experiments. The prefix SF designates the three specimens used to determine inherent corrosion-protecting ability in salt spray. The additional designations U, R_C, and I indicate which specimens were exposed to salt spray undamaged, damaged with Rockwell-C hardness indentations, or damaged by the four-ft.-lb. impact blow, respectively. The three specimens used to determine inherent flexibility are identified by the prefix F. The remaining six specimens that were exposed to 650° F were given the prefix TE, which is followed by a letter A, B, or C corresponding to Series A, B, or C thermal cycling procedures. Three of these six specimens were subsequently exposed to salt spray, as designated by the suffix SF, and the last three were used in flexibility determinations marked by the suffix F.

Results of Experiments

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
1	Metallic	Electrophoretic & Rolled Aluminum[3]	SF-U-9	U	Light white discoloration over 90% of surface area. Substrate appears uncorroded.
			SF-R_C-9	R_C	Light white discoloration over 100% of surface area. Substrate appears uncorroded.
			SF-I-9	I	Light white discoloration over 90% of surface area. Substrate appears uncorroded.
			F-1	U	No cracks
			F-2	U	Scored line opened.
			F-3	U	No cracks.
			TE-A-17	A	Unchanged.
			TE-A-18	A	Unchanged.
			TE-B-17	B	Unchanged.
			TE-B-18	B	Unchanged.
			TE-C-17	C	Slight surface stains.
			TE-C-18	C	Slight surface stains.
			TE-A-17-SF	A	Light white discoloration over 75% of surface area. Substrate appears uncorroded.
			TE-B-17-SF	B	Very light white discoloration over 100% of surface area. Substrate appears uncorroded.
			TE-C-17-SF	C	Light white discoloration over 100% of surface area. Substrate appears uncorroded.
			TE-A-18-F	A	No cracks.
			TE-B-18-F	B	No cracks.
			TE-C-18-F	C	No cracks.
2	Metallic	Flame-Sprayed Aluminum	SF-U-10	U	Light white discoloration over 10% of surface area. Substrate appears uncorroded.
			SF-R_C-10	R_C	Slight rust discoloration, but not at R_C indentations.
			SF-I-10	I	Light white discoloration over 10% of surface area. Substrate appears uncorroded.
			F-1	U	Short cracks on 1/2-in.-diameter edge.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-19	A	Unchanged.
			TE-A-20	A	Unchanged.
			TE-B-19	B	Unchanged.
			TE-B-20	B	Unchanged.
			TE-C-19	C	Unchanged.
			TE-C-20	C	Unchanged.
			TE-A-19-SF	A	White discoloration and moderate deposits over 100% of surface area. Substrate appears uncorroded.
			TE-B-19-SF	B	White discoloration and moderate deposits over 100% of surface area. Substrate appears uncorroded.
			TE-C-19-SF	C	White discoloration and moderate deposits over 100% of surface area. Substrate appears uncorroded.
			TE-A-20-F	A	No cracks.
			TE-B-20-F	B	No cracks.
			TE-C-20-F	C	No cracks.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
3	Metallic	Vacuum-Deposited Aluminum	SF-U-23	U	Dark spot corrosion and corrosive flow over 75% of surface area.
			SF-R_c-23	R_c	Dark spot corrosion and corrosive flow over 60% of surface area.
			SF-I-23	I	Dark spot corrosion and corrosive flow over 90% of surface area.
			F-1	U	No cracks.
			TE-B-44	B	Discoloration over 100% of surface area.
			TE-B-45	B	Discoloration over 100% of surface area.
			TE-B-45-SF	B	Dark spot corrosion and corrosive flow over 20% of surface area. Moderate discoloration.
			TE-B-44-F	B	No cracks.
4	Metallic	Diffused Aluminum-Iron	SF-U-21	U	Rust deposits over 100% of surface area.
			SF-R_c-21	R_c	Rust deposits over 100% of surface area.
			SF-I-21	I	Rust deposits over 100% of surface area.
			F-1	U	Specimen fractured in a brittle manner.
			F-2	U	Specimen fractured in a brittle manner.
			F-3	U	Not evaluated because only eleven specimens were supplied.
			TE-A-42	A	Slight heat-tint discoloration.
			TE-A-43	A	Slight heat-tint discoloration.
			TE-B-42	B	Slight heat-tint discoloration.
			TE-B-43	B	Slight heat-tint discoloration.
			TE-C-42	C	Slight heat-tint discoloration.
			TE-C-43	C	Slight heat-tint discoloration.
			TE-A-43-SF	A	Rust deposits over 100% of surface area.
			TE-B-43-SF	B	Rust deposits over 100% of surface area.
			TE-C-43-SF	C	Rust deposits over 100% of surface area.
			TE-A-42-F	A	Specimen fractured in a brittle manner.
			TE-B-42-F	B	Specimen fractured in a brittle manner.
			TE-C-42-F	C	Specimen fractured in a brittle manner.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage	Results of Visual Examination[2]
7	Metallic	Electroplated and Hot-Rolled Nickel	SF-U-15	U	Dark and light discolorations over 100% of surface area. Substrate appears uncorroded[3].
			SF-R_c-15	R_c	Dark and light discolorations over 100% of surface area. No rust at R_c indentations. Substrate appears uncorroded.
			SF-I-15	I	Dark and light discolorations over 100% of surface area. No rust at impact area. Substrate appears uncorroded.
			F-1	U	No cracks.
			F-2	U	No cracks.
			F-2	U	No cracks.
			TE-A-31	A	Slight heat-tint over 20% of surface area. Other discolorations appeared on the panel as-received.
			TE-A-32	A	Unchanged. Discolorations appeared on the panel as-received.
			TE-B-31	B	Moderate heat-tint discoloration over 100% of surface area. "Pepper-like" and white discolorations appeared on the panel as-received.
			TE-B-32	B	Moderate heat-tint discoloration over 100% of surface area. "Pepper-like" and white discolorations appeared on the panel as-received.
			TE-C-31	C	Moderate heat-tint discoloration over 70% of surface area. White discolorations appeared on the panel as-received.
			TE-C-32	C	Moderate heat-tint discoloration over 20% of surface area. White discolorations appeared on the panel as-received.
			TE-A-31-SF	A	Dark and light discolorations over 100% of surface area. Substrate appears uncorroded[4].
			TE-B-31-SF	B	Dark and light discolorations over 100% of surface area. Substrate appears uncorroded[4].
			TE-C-31-SF	C	Light discolorations over 75% of surface area. Substrate appears uncorroded.[4]
			TE-A-32-F	A	No cracks.
			TE-B-32-F	B	No cracks.
			TE-C-32-F	C	No cracks.
8	Metallic	Electroplated Nickel & Cadmium	SF-U-6	U	White and gray deposits over 100% of surface area. Substrate appears uncorroded.
			SF-R_c-6	R_c	White and gray deposits over 100% of surface area. Substrate appears uncorroded.
			SF-I-6	I	White and gray deposits over 100% of surface area. Substrate appears uncorroded.
			F-1	U	No cracks.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-11	A	Unchanged. Heat-tint discolorations occurred during diffusion heat treatment.
			TE-A-12	A	Unchanged. Heat-tint discolorations occurred during diffusion heat treatment.
			TE-B-11	B	Unchanged. Heat-tint discolorations occurred during diffusion heat treatment.
			TE-B-12	B	Unchanged. Heat-tint discolorations occurred during diffusion heat treatment.
			TE-C-11	C	Discolorations over 30% of surface area.
			TE-C-12	C	Discolorations over 10% of surface area.
			TE-A-11-SF	A	Dark gray and light gray deposits over 100% of surface area. Substrate appears uncorroded.
			TE-B-11-SF	B	Dark gray and light gray deposits over 100% of surface area. Substrate appears uncorroded.
			TE-C-11-SF	C	Dark gray and light gray deposits over 100% of surface area. Substrate appears uncorroded.
			TE-A-12-SF	A	No cracks.
			TE-B-12-F	B	No cracks.
			TE-C-12-F	C	No cracks.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
9	Metallic	Electroless Nickel Alloy	SF-U-14	U	Rust over 20% of surface area.
			SF-R_c-14	R_c	Rust and flow from bottom R_c indentation.
			SF-I-14	I	Rust over 40% of surface area and over area of impact.
			F-1	U	Cracks extending completely across the specimen.
			F-2	U	Cracks extending completely across the specimen.
			F-3	U	Cracks extending completely across the specimen.
			TE-A-27	A	Slight heat-tint over 100% of surface area.
			TE-A-28	A	Slight heat-tint over 100% of surface area.
			TE-B-27	B	Spot discolorations.
			TE-B-28	B	Spot discolorations.
			TE-C-27	C	Spot discolorations.
			TE-C-28	C	Spot discolorations.
			TE-A-27-SF	A	Rust streaks over 75% of surface area.
			TE-B-27-SF	B	Rust streaks over 75% of surface area.
			TE-C-27-SF	C	Rust streaks over 75% of surface area.
			TE-A-28-F	A	Small cracks on both edges.
			TE-B-28-F	B	Small cracks at 1/2-in. diameter edge.
			TE-C-28-F	C	Small cracks on both edges.
11	Metallic	Cold-Galvanized Zinc	SF-U-17	U	White discoloration over 50% of surface area. Substrate appears uncorroded.
			SF-R_c-17	R_c	White discoloration over 40% of surface area. Substrate appears uncorroded.
			SF-I-17	I	White discoloration over 60% of surface area. Substrate appears uncorroded.
			F-1	U	Cracks extending completely across the specimen.
			F-2	U	Cracks extending completely across the specimen.
			F-3	U	Cracks extending completely across the specimen.
			TE-A-35	A	Three wavy-line discolorations.
			TE-A-36	A	Unchanged.
			TE-B-35	B	White discolorations over 10% of surface area.
			TE-B-36	B	White discolorations over 20% of surface area.
			TE-C-35	C	Unchanged.
			TE-C-36	C	Unchanged.
			TE-A-35-SF	A	Heavy white and gray deposits over 100% of surface area. Substrate appears uncorroded.
			TE-B-35-SF	B	Heavy white and gray deposits over 100% of surface area. Substrate appears uncorroded.
			TE-C-35-SF	C	White and gray deposits over 100% of surface area. Substrate appears uncorroded.
			TE-A-36-F	A	Cracked on both edges.
			TE-B-36-F	B	Cracked on both edges.
			TE-C-36-F	C	Edge cracks.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
12	Metallic	Hot-Dip Galvanized Zinc	SF-U-8	U	Heavy white deposits over 100% of surface area. Substrate appears uncorroded.
			SF-R_c-8	R_c	Heavy white deposits over 100% of surface area. Substrate appears uncorroded.
			SF-I-8	I	Heavy white deposits over 100% of surface area. Substrate appears uncorroded.
			F-1	U	Cracks on 1/2-in.-diameter edge.
			F-2	U	Cracks on 1/2-in.-diameter edge.
			F-3	U	Cracks on 1/2-in.-diameter edge.
			TE-A-15	A	Discoloration over 10% of surface area.
			TE-A-16	A	Discoloration over 10% of surface area.
			TE-B-15	B	Discoloration over 100% of surface area.
			TE-B-16	B	Discoloration over 50% of surface area.
			TE-C-15	C	Light discoloration over 5% of surface area.
			TE-C-16	C	Light discoloration over 20% of surface area.
			TE-A-15-SF	A	Heavy white deposits over 100% of surface area. Substrate appears uncorroded.
			TE-B-15-SF	B	Heavy white deposits over 100% of surface area. Substrate appears uncorroded.
			TE-C-15-SF	C	Heavy white deposits over 100% of surface area. Substrate appears uncorroded.
			TE-A-16-F	A	No cracks.
			TE-B-16-F	B	Crack extending from 1/2-in.-diameter edge to 5/8-in. diameter position.
			TE-C-16-F	C	Small cracks extending completely across the specimen.
16	Organic	Thermosetting Polymer[5]	SF-U-1	U	Nil.
			SF-R_c-1	R_c	Rust spots at each R_c indentation.
			SF-I-1	I	Rust spot at point of most severe impact.
			F-1	U	Coating tore away from substrate.
			F-2	U	Coating tore away from substrate.
			F-3	U	Coating tore away from substrate.
			TE-A-1	A	Coating cracked into several pieces and separated from substrate.
			TE-A-2	A	Coating cracked into several pieces and separated from substrate.
			TE-B-1	B	Coating cracked into several pieces and separated from substrate.
			TE-B-2	B	Coating cracked into several pieces and separated from substrate.
			TE-C-1	C	Coating cracked into several pieces and separated from substrate.
			TE-C-2	C	Coating cracked into several pieces and separated from substrate.

Results of Experiments(Continued)

No.	Category	Type of Coating	Specimen No[1].	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
17	Organic	Aluminum-Modified Silicone	SF-U-11	U	Random point-corrosion over 20% of surface area.
			SF-R_c-11	R_c	Rust spot at center R_c indentation.
			SF-I-11	I	Rust at area of impact.
			F-1	U	No cracks. Specimen was scored by mandrel.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-21	A	Unchanged.
			TE-A-22	A	Unchanged.
			TE-B-21	B	Slight surface stain.
			TE-B-22	B	Slight surface stains.
			TE-C-21	C	Unchanged.
			TE-C-22	C	Unchanged.
			TE-A-21-SF	A	Random slight point-corrosion over 20% of surface area.
			TE-B-21-SF	B	Random slight point-corrosion over 20% of surface area.
			TE-C-21-SF	C	Random slight point-corrosion over 20% of surface area.
			TE-A-22-F	A	Small cracks at both edges.
			TE-B-22-F	B	No cracks.
			TE-C-22-F	C	No cracks.
18	Organic	Catalytically Cured Silicone	SF-U-22	U	Light point corrosion
			SF-R_c-22	R_c	Light point corrosion. Point-rust spots in R_c indentations.
			SF-I-22	I	Light point corrosion. Rust spot at point of most severe impact.
			F-1	U	No cracks.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-40	A	Unchanged.
			TE-A-41	A	Unchanged.
			TE-B-40	B	Unchanged.
			TE-B-41	B	Unchanged.
			TE-C-40	C	Mosaic pattern of cracks over 40% of surface area.
			TE-C-41	C	Mosaic pattern of cracks over 40% of surface area.
			TE-A-41-SF	A	Light point corrosion.
			TE-B-41-SF	B	Light point corrosion.
			TE-C-41-SF	C	Rusted where coating cracked off during Series C.
			TE-A-40-F	A	Cracks extending completely across the specimen.
			TE-B-40-F	B	Cracks extending completely across the specimen.
			TE-C-40-F	C	Cracks extending completely across the specimen.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
19	Organic	Silicone Resin Vehicle[6]	SF-U-2	U	Three isolated-point rust spots.
			SF-R_c-2	R_c	Rust spots and flow at and from each R_c indentation.
			SF-I-2	I	Rust spot and flow at point of most severe impact.
			F-1	U	No cracks.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-3	A	Beige-colored heat-tint discoloration over 90% of surface area.
			TE-A-4	A	Beige-colored heat-tint discoloration over 90% of surface area.
			TE-B-3	B	70% of coating cracked and separated from substrate.
			TE-B-4	B	40% of coating cracked and separated from substrate.
			TE-C-3	C	100% of coating separated from substrate.
			TE-C-4	C	30% of coating separated from substrate.
			TE-A-3-SF	A	Rust over 75% of surface area.
			TE-A-4-F	A	Coating cracked and separated from substrate.
			TE-B-4-F	B	Coating flaked off substrate. Most of it had separated from substrate during Series B temperature exposures.
20	Organic	Teflon in Silicone Resin	SF-U-12	U	Nil.
			SF-R_c-12	R_c	Rust spots at each R_c indentation and at penciled identification mark.
			SF-I-12	I	Rust spot on impact area.
			F-1	U	No cracks.
			F-2	U	Edge failures.
			F-3	U	No cracks
			TE-A-23	A	Unchanged.
			TE-A-24	A	Unchanged.
			TE-B-23	B	White spot discolorations.
			TE-B-24	B	White spot discolorations.
			TE-C-23	C	Irregularly shaped discoloration and spots over 70% of surface area.
			TE-C-24	C	Irregularly shaped discoloration and spots over 90% of surface area.
			TE-A-23-SF	A	Light discoloration. Substrate appears uncorroded.
			TE-B-23-SF	B	Light point corrosion.
			TE-C-23-SF	C	Discoloration over 80% of surface area and moderate point corrosion.
			TE-A-24-F	A	No cracks. Coating was partially scraped off when specimen was removed from apparatus.
			TE-B-24-F	B	No cracks.
			TE-C-24-F	C	No cracks.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[a]
21	Semi-Organic	Silicon-Nitrogen Polymer	SF-U-5	U	Large rust spots.
			SF-R_c-5	R_c	Large rust spots. Rust at each R_c indentation. Discolorations occurred prior to salt-spray evaluation.
			SF-I-5	I	Substrate corrosion over 30% of surface area and at point of most severe impact.
			F-1	U	No cracks.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-9	A	Discoloration over 10% of surface area.
			TE-A-10	A	Discoloration over 30% of surface area.
			TE-B-9	B	Darker discoloration than that resulting from Series A over 30% of surface area.
			TE-B-10	B	Darker discoloration than that resulting from Series A over 10% of surface area.
			TE-C-9	C	Dark discolorations over 10% of surface area.
			TE-C-10	C	Dark discolorations over 5% of surface area.
			TE-A-9-SF	A	Irregular rust areas and spots over 50% of surface area.
			TE-B-9-SF	B	Rust flow and spots over 60% of surface area.
			TE-C-9-SF	C	Rust spots over 25% of surface area.
			TE-A-10-F	A	No cracks.
			TE-B-10-F	B	No cracks.
			TE-C-10-F	C	No cracks.
24	Inorganic	Flame-Sprayed Aluminum Oxide	SF-U-13	U	Random rust spots over 80% of surface area.
			SF-R_c-13	R_c	Random rust spots covering 10% of surface area. Rust in all three R_c indentations.
			SF-I-13	I	Rust spots over 10% of surface area. No rust at area of impact.
			F-1	U	Cracks extending completely across the specimen.
			F-2	U	Cracks extending completely across the specimen.
			F-3	U	Cracks extending completely across the specimen.
			TE-A-25	A	Unchanged.
			TE-A-26	A	Unchanged.
			TE-B-25	B	Five random spot discolorations.
			TE-B-26	B	Five random spot discolorations.
			TE-C-25	C	Unchanged.
			TE-C-26	C	Unchanged.
			TE-A-25-SF	A	One rust streak and light point corrosion.
			TE-B-25-SF	B	Light point corrosion.
			TE-C-25-SF	C	Light point corrosion.
			TE-A-25-F	A	Small cracks at both edges.
			TE-B-25-F	B	Flaked at 1/2-in. diameter edge.
			TE-C-25-F	C	No cracks.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
25	Inorganic	Fused Minerals	SF-U-7	U	Rust over 25% of surface area.
			SF-R_c-7	R_c	Rust and flow at each Rc indentation.
			SF-I-7	I	Rust and flow from impact area and over 5% of surface area.
			F-1	U	Cracked at both edges.
			F-2	U	Cracked at both edges.
			F-3	U	Cracked at both edges.
			TE-A-13	A	Slight discoloration over 90% of surface area.
			TE-A-14	A	Unchanged.
			TE-B-13	B	Discoloration over 95% of surface area.
			TE-B-14	B	Discoloration over 95% of surface area.
			TE-C-13	C	Light discoloration over 30% of surface area.
			TE-C-14	C	Light discoloration over 90% of surface area.
			TE-A-13-SF	A	Rust areas over 10% of surface area.
			TE-B-13-SF	B	Three rust spots over 20% of surface area.
			TE-C-13-SF	C	Rust flow and spots over 20% of surface area.
			TE-A-14-F	A	Small cracks at both edges.
			TE-B-14-F	B	Coating and substrate cracked when specimen was bent only 90°.
			TE-C-14-F	C	Flaked on concave side.
27	Inorganic	Zinc Silicate	SF-U-4	U	Discoloration over 30% of surface area. Substrate appears uncorroded.
			SF-R_c-4	R_c	Discoloration over 50% of surface area. Substrate appears uncorroded.
			SF-I-4	I	Discoloration over 50% of surface area. Substrate appears uncorroded.
			F-1	U	Small cracks extending from 1/2-in.-diameter edge to 7/8-in.-diameter position. Cracked on both edges.
			F-2	U	Small cracks extending from 1/2-in.-diameter edge to 7/8-in.-diameter position. Cracked on both edges.
			F-3	U	Small cracks extending from 1/2-in.-diameter edge to 7/8-in.-diameter position. Cracked on both edges.
			TE-A-7	A	Unchanged.
			TE-A-8	A	Unchanged.
			TE-B-7	B	Spotty and irregularly shaped separation of 30% of coating from substrate.
			TE-B-8	B	Irregularly shaped separation of 60% of coating from substrate.
			TE-C-7	C	Unchanged.
			TE-C-8	C	Unchanged.
			TE-A-7-SF	A	White deposits over 60% of surface area. Discoloration over 100% of surface area. Substrate appears uncorroded.
			TE-B-7-SF	B	Heavy white deposits over 90% of surface area. Discoloration over 100% of surface area. Substrate appears uncorroded.
			TE-C-7-SF	C	White deposits over 50% of surface area. Substrate appears uncorroded.
			TE-A-8-F	A	Cracks extending from 1/2-in.-diameter edge to 9/16-in.-diameter position. Cracks at both edges.
			TE-B-8-F	B	Not evaluated - coating had separated in Series B heat exposure.
			TE-C-8-F	C	Cracks at 3/4-in.-diameter position. Cracks at both edges.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
28	Other	A-61110-50 (Aircraft White)	SF-U-3	U	Light point corrosion.
			SF-R_c-3	R_c	Substrate corrosion over 2% of surface area and rust spots at top and bottom R_c indentation.
			SF-I-3	I	Substrate corrosion over 5% of surface area and rust over 2/3 of area of impact.
			F-1	U	No cracks.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-5	A	Slight discoloration over 100% of surface area.
			TE-A-6	A	Slight discoloration over 100% of surface area.
			TE-B-5	B	Slight discoloration over 100% of surface area.
			TE-B-6	B	Slight discoloration over 100% of surface area.
			TE-C-5	C	Mosaic pattern of cracks over 100% of surface area.
			TE-C-6	C	Mosaic pattern of cracks over 100% of surface area.
			TE-A-5-SF	A	Moderate point corrosion
			TE-B-5-SF	B	Moderate point corrosion and rust smudge over 20% of surface area.
			TE-C-5-SF	C	Heavy point corrosion.
			TE-A-6-F	A	*Discontinuous cracks extending from 1/2-in. -diameter edge to 3/4-in. -diameter position.* Short cracks at 1/2-in. -diameter edge.
			TE-B-6-F	B	Cracks extending completely across the specimen.
			TE-C-6-F	C	Cracks extending completely across the specimen.
30	Other	Heat-Resistant Coating 57X50	SF-U-18	U	White deposits and streaks over 50% of surface area. Substrate appears uncorroded.
			SF-R_c-18	R_c	White deposits and streaks over 50% of surface area. Substrate appears uncorroded.
			SF-I-18	I	White deposits and streaks over 50% of surface area. Substrate appears uncorroded.
			F-1	U	No cracks.
			F-2	U	Small cracks extending from 1/2-in.-diameter edge to 5/8-in. -diameter position.
			F-3	U	Small cracks extending from 1/2-in.-diameter edge to 9/16-in. -diameter position.
			TE-A-37	A	Unchanged.
			TE-A-38	A	Unchanged.
			TE-B-37	B	White discolorations over 40% of surface area.
			TE-B-38	B	White discolorations over 60% of surface area.
			TE-C-37	C	Extensive cracking at one edge.
			TE-C-38	C	Extensive cracking at both edges.
			TE-A-37-SF	A	White deposits over 80% of surface area. Substrate appears uncorroded.
			TE-B-37-SF	B	White deposits over 80% of surface area. Substrate appears uncorroded.
			TE-C-37-SF	C	White deposits over 90% of surface area. Substrate appears uncorroded.
			TE-A-38-F	A	Cracks extending completely across the specimen.
			TE-B-38-F	B	Cracks extending completely across the specimen.
			TE-C-38-F	C	No cracks caused by bending.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
32	Other	"DA-9" Aluminum	SF-U-16	U	Unchanged except for one light discolored spot about 1/2-in. in diameter. Substrate appears uncorroded.
			SF-R_c-16	R_c	Rust and flow from all 3 R_c indentations.
			SF-I-16	I	Rust over area of impact and rust flow from point of most severe impact.
			F-1	U	No cracks.
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-29	A	Slight discoloration over 100% of surface area.
			TE-A-30	A	Slight discoloration over 100% of surface area.
			TE-B-29	B	Slight discoloration over 100% of surface area and spot discolorations.
			TE-B-30	B	Slight discoloration over 100% of surface area and spot discolorations.
			TE-C-29	C	Slight discoloration over 100% of surface area and spot discolorations.
			TE-C-30	C	Slight discoloration over 100% of surface area and spot discolorations.
			TE-A-29-SF	A	Rust deposits over 90% of surface area.
			TE-B-29-SF	B	Rust deposits over 95% of surface area.
			TE-C-29-SF	C	Rust deposits over 50% of surface area.
			TE-A-30-F	A	No cracks.
			TE-B-30-F	B	No cracks.
			TE-C-30-F	C	No cracks.
33	Other	"Pyre-M. L." Varnish	SF-U-20	U	Light discolorations over 20% of surface area. Substrate appears uncorroded.
			SF-R_c-20	R_c	Rust at each R_c indentation. Light discolorations over 10% of surface area.
			SF-I-20	I	Rust at area of impact. Light discolorations over 10% of surface area.
			F-1	U	No cracks
			F-2	U	No cracks.
			F-3	U	No cracks.
			TE-A-33	A	Heat-tint discoloration over 100% of surface area.
			TE-A-34	A	Heat-tint discoloration over 100% of surface area.
			TE-B-33	B	55% of coating peeled from its substrate. Heat-tint discoloration over 100% of surface area.
			TE-B-34	B	Heat-tint discoloration over 100% of surface area.
			TE-C-33	C	Heat-tint discoloration over 100% of surface area.
			TE-C-34	C	Heat-tint discoloration over 100% of surface area.
			TE-A-33-SF	A	Light discoloration. Substrate appears uncorroded.
			TE-B-33-SF	B	Not evaluated because most of the coating peeled from substrate during Series B heat exposure.
			TE-C-33-SF	C	Discoloration over 50% of surface area. Substrate appears uncorroded.
			TE-A-34-F	A	No cracks.
			TE-B-34-F	B	Edge failures.
			TE-C-34-F	C	No cracks.

Results of Experiments (Continued)

No.	Category	Type of Coating	Specimen No.[1]	Prior Mechanical or Thermal Damage[1]	Results of Visual Examination[2]
X	Control	7075 Clad Aluminum	SF-U-19	U	White deposits and dark discolorations over 100% of surface area.
			SF-R_c-19	R_c	White deposits and dark discolorations over 100% of surface area.
			SF-I-19	I	White deposits and dark discolorations over 100% of surface area.
			TE-A-39	A	One white-spot discoloration.
			TE-B-39	B	Three white-spot discolorations.
			TE-C-39	C	Unchanged.
			TE-A-39-SF	A	White deposits and gray streaks over 60% of surface area.
			TE-B-39-SF	B	White deposits and gray streaks over 60% of surface area.
			TE-C-39-SF	C	White deposits and gray streaks over 40% of surface area.

[1] SF designates salt-spray evaluation; U designates undamaged condition; R_c designates three Rockwell-C indentations; I designates one four-ft-lb impact blow; TE designates temperature exposure; A, B, and C designate series of temperature exposures shown in Figure 1; F designates flexibility evaluation.
[2] After salt spray, the water-rinsed and air-dried upper side of each specimen was visually examined, excluding the section inserted into the support rack. After each series of temperature exposures, the upper side of each specimen was visually examined. The flexibility evaluations were made on the convex side of the bend. All percentages are estimates.
[3] Coated on mild steel substrate.
[4] Rust streaks flowed from specimen edges under paraffin seal.
[5] Specimens that received the temperature exposures were not subjected to salt spray or flexibility evaluations because the coatings had separated from their substrates.
[6] Specimens TE-B-3-SF and TE-C-3-SF were not subjected to salt-spray evaluation and specimen TE-C-4-F was not bent because the coatings had separated from their substrates.